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CONTENTS

Progress and Developments in Dams, Supply Lines, and Pumping Equipment. By L. R. Howson 1429
Two-Inch Cast Iron Pipe. By J. D. Sample 1438
Treatment and Purification of Water—Progress and Developments During 1936. By Paul Hansen 1443
Report of the Joint Research Committee on Boiler Feedwater Studies. By C. H. Fellows 1467
A Study of Contemporary Zeolites. By Leo F. Collins ... 1472
Observations on Zeolites in Water Softening and Demanganization. By D. E. Davis 1515
Removal of Dissolved Mineral Solids from Water by Organic Exchange Filters. By P. G. Bird, W. H. Kirkpatrick and Easton Melof 1526
Coagulation as Applied to Industrial Waters. By A. P. Black, R. A. Bardwell and B. W. Graham 1533
The Diversified Activities of our Water Sales Division. By Thad M. Erwin 1548
Creating and Retaining Customers' Good-Will. By H. L. Meites 1560
Internal Audit and Control. By Paul D. Williams 1566
Discussion by E. C. Schwier 1577
Can A Municipal Water Works be Economically Operated? By Wendell R. LaDue 1580
Some Notes on Sand Filtration. By Tomihisa Iwasaki. 1591
Discussion by J. J. Slade, Jr. 1597
Wm. E. Stanley 1601
Experiences with Activated Carbon at Hammond, Indiana. By Leo Besozzi and J. C. Vaughn 1603
Discussion by Mathew M. Braidech 1629
Abstracts 1640
Coming Meetings v
Additions to Membership List vi
News of the Field 1

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Vol. 29 OCTOBER, 1937 No. 10

PROGRESS AND DEVELOPMENTS IN DAMS, SUPPLY LINES, AND PUMPING EQUIPMENT*

BY L. R. HOWSON

(*Alvord, Burdick and Howson*)

Progress and developments in reservoirs, supply lines, and pumping as in many other similar lines of endeavor, is usually evolutionary rather than revolutionary. Accordingly, it is difficult to isolate the developments within a year from the progress which has been taking place and maturing for a considerable period. It, therefore, may well be that some of what will be referred to herein as developments during the year may be the culmination or exposing to view of maturing tendencies.

Many large reservoir projects are now in progress. Some of them will be referred to more specifically hereinafter as illustrating the generalization as to progress.

DAMS

Earth and rock fill dams continue to be most largely used for water supply purposes. There has been a marked improvement in the design and construction of such structures. The integrity of the rock fill type of dam has been greatly improved by the placing of a relatively impervious earth fill at or near the upstream face instead

* Presented at the Buffalo convention, June 10, 1937.

of the usual concrete or rock slab facing and by flushing fine materials into the voids of the stone so as to minimize settlement. The San Gabriel dams of Los Angeles are excellent illustrations of progress in this phase of dam design.

The construction of earth fill dams has been put on a much sounder engineering basis in recent years. Time only can tell how superior the results will be as compared to results secured heretofore without the technical control but under experienced dam builders. It would seem likely that the uniformity of results will at least be much better assured. The principal improvements in earth dam construction consist of:

(a) Scientific selection and grading of materials.
(b) Control of moisture and development of means for testing compacting.
(c) The development of machinery for compacting.
(d) A better understanding of the conditions which have led to earlier failures.

In general, it may be stated that practically any material can be used some place in a well designed earth dam and that when earth embankment structures are provided with spillways adequate to prevent overtopping and with protection against infiltration along the contact between the embankment and its foundation, the earth dam is one of the safest structures.

The construction of large dams has led to the development of large equipment and the placing of quantities previously considered impossible. The earth dam of today is entirely mechanized. The horse and mule with their picturesque "skinners" are no more. In their place are the dragline, steam shovel, truck and caterpillar-drawn rollers. Draglines with buckets excavating in excess of 30 cubic yards per lift, and trucks carrying from 30 to 35 cubic yards per load from the draglines to the embankment, are the rule on large jobs. At Fort Peck during August 1936 a total of 4,300,000 cubic yards was pumped into the dam exceeding the prior month's record of 3,724,000 cubic yards made in May. At Grand Coulee the concrete equipment is geared to place approximately 7,000 cubic yards of concrete per day. At the Parker dam, where there are twin 32 foot diameter tunnels, a drill jumbo was designed with working platforms at three levels and mountings for nineteen drills. This equipment made 25 feet drilling progress a day.

Among the larger dam construction jobs now in progress, are included:

(a) At *Little Rock* in connection with the new water supply, an earth dam 2,800 feet long with a maximum height of 115 feet above bed rock and containing 1,335,000 cubic yards, is now under construction. In selecting the location and type of dam, extensive geological borings were made and the services of the State Geologist were called in to assist the engineers in charge of the design. Rolling is done with sheep's foot rollers and compaction is carefully controlled and checked. The center impervious section has 1:1 slopes and is spread in 8-inch layers. At least eight passages of the sheep's foot roller are required. Downstream face is pervious material and upstream pervious to semi pervious. Slopes vary from 1:1.8 at top to 1:2.75 at bottom. In the design of the "around the end" type of spillway for Little Rock a model was made and tested at the Hydraulic Laboratory at Iowa State College.

(b) At *Denver* in connection with the new Moffat tunnel transmountain water diversion project there is under construction at Ralston Lake a 185 foot high earthen embankment, the type being selected after a careful investigation of subsurface conditions, construction materials, and cost. The dam has an impervious core of selected materials with pervious upstream and downstream faces. The impervious section occupies about the middle third of the embankment.

The upstream slopes vary from 1 to 2½ at the top to 1:4 at the toe. The downstream slope is uniform at 1:2½ terminating in a heavy rock toe section. All materials are continually checked by a soils laboratory at the site of the job. The contractor may be required to mix materials from two or more borrow pits if unable to locate pit materials of the required character. Impervious material is rolled in 6-inch layers with sheep's foot rollers whose weight is at least 250 pounds per square inch of foot area. The number of passes of the roller is determined by tests of compacted material. Passes in excess of twelve, if required, are paid for as an extra. Extensive explorations were made to determine the availability of suitable materials particularly for the impervious center. The entire design is based upon an impervious center with porous, free draining supports compacted so as to avoid settlement.

(c) *Colorado Springs* has constructed its second rock fill dam with a steel upstream face. The face is anchored into the rock or cut-off wall at the sides and a heavy reinforced concrete apron at the bottom of the site, and is welded throughout, making the whole face

of the dam a continuous steel sheet. Expansion is taken care of by building U shaped troughs running up and down the slope at about 25 feet centers. Plates are ¼-inch thick and are put in place on a light framework which extends 3 inches beyond the face of the dam. This space is filled with gravel after the erection and painting of the underside of the plates with red lead. The exterior is painted with gray lead and oil to provide minimum heat absorption. Other dams of this type have been built in the Colorado area.

(d) At *Los Angeles*, following the settlement of San Gabriel rock fill dam No. 2, the engineers of the Los Angeles flood control district with their Consulting Boards have carefully studied the causes for that failure and in the redesign of San Gabriel dam No. 1, which is also of rock fill construction, they have provided for the flushing of fine material into the voids of the rock in one zone of the fill so as to make the upstream half as impervious as practicable. This zone is near the upstream face but is protected against erosion and drying out by a heavy blanket of unselected rock. It is believed that this provision will materially improve the adaptability of the rock fill dam for water storage purposes.

(e) At *Fort Smith, Ark.*, a dam containing approximately 1,000,000 cubic yards has been built with its upstream half of impervious carefully compacted materials and its downstream face of pervious materials largely rock, gravel and shale.

While possibly elevated tanks pertain to distribution system rather than reservoirs, it is believed worth while in passing to mention the fact that in the last few years elevated storage in large steel tanks has become increasingly common as its economics are better understood. There are now over 60 elevated tanks in the United States exceeding 1 million gallons in size. Racine and Kenosha, Wis., have constructed standpipes holding approximately 3 million gallons each with the top half available for high service storage and the bottom half made available by pumps, if desired, when the water level is drawn below mid-height. These two tanks are illustrations of an economic comparison between elevated storage on towers and elevated storage in standpipes with the lower part largely used as reserve clear water storage.

The State of California has recently completed an examination of over 900 dams more than 25 feet in height (one-third of which needed repairs). Of these dams approximately 70 percent were of the earth or rock fill type and 30 percent of masonry construction. The worst

faults in the California dams considered in their order of frequency of occurrence, were listed as follows:

(a) Inadequate spillway.
(b) Inadequate treatment of foundations.
(c) Lack of protection against erosion.
(d) Poor materials and poor construction methods.

Two recent examples of earth dam failures due to overtopping, both due to inadequate spillway were presented at Herrin, Ill., and Elk City, Okla. In the latter case, with a dam built but a few years ago, the spillway even though inadequate for the flood which afterward destroyed the dam, had been reduced by half two years ago in an effort to store more water; thus an inadequate spillway with its capacity still further reduced, contributed to the total loss of the dam.

SUPPLY LINES

So far as water supply is concerned, progress in the last year has been signalized by the construction of lines of larger diameter and for higher pressure than previously used for precast reinforced concrete pipe. During the year the first major industrial water supply development and many long conduit lines have been built.

The use of steel pipe in the larger sizes has received renewed impetus due to the development of spun bitumastic linings which give promise of solving the corrosion disadvantage previously charged against steel pipe. This coating is so smooth as to entitle steel pipe to a Hazen-Williams coefficient of approximately 130 to 140 (comparable to the best concrete pipe) and data thus far available indicate that its capacity is well maintained. Particularly in the larger sized conduits more attention is being given to the carrying capacity purchased per dollar and the probability of maintaining that investment at as near par as practicable. Smooth surfaces capable of being maintained, combined in some cases with treatment of the water so as to decrease its tendency to cause deterioration in pipe and castings, are all making substantial progress.

This spun bitumastic lining is applied to the pipe after it has been thoroughly cleaned of all rust and mill scale and after priming, by revolving the pipe at a suitable speed while the hot bitumastic lining is applied to the inside surface. The thickness of the bitumastic linings is generally specified at about $\frac{3}{32}$-inch with a tolerance of $\frac{1}{32}$-inch plus or minus. The exterior coating which is usually poured

or spread while the pipe is still revolving, is about $\frac{1}{16}$-inch in thickness and coated with whitewash to make apparent any abrasions in handling. The leading bitumastic products companies have developed enamels which are tough and which will neither flow nor crack within a wide range of temperatures.

Another decided tendency in supply line construction is the use of automatic cone or plug type valves which will isolate breaks and minimize damage resulting therefrom. The operation of these valves can be so timed as to minimize surges and if necessary, the installation can be further protected by relief valves which come into operation only when the pressure exceeds a predetermined amount. It is believed that the use of valves of this type will also become more frequent in large feeder lines in the distribution system. Large mains have heretofore been controlled almost exclusively by gate valves, which are either difficult or impossible to close under free flow conditions resulting from line break.

There have been a number of large main breakages during the past year, some of which resulted in serious property damage. Probably the most serious was the break in a 36-inch line near the Post Office in Chicago which flooded the basement of the Post Office, ran through into the Union Station, locked all of the switching devices on the tracks entering that station from the south and completely isolated the Union Station to all train service from that direction for nearly twenty-four hours. This break also indicates one of the reasons why in large sized conduits increasingly greater proportions are being built of reinforced concrete and steel, materials which do not fail suddenly like cast iron.

Denver had a spectacular break in a 36-inch wood stave conduit due to the failure of several steel bands and the breaking out of pieces of two staves each about 5 inches by 18 inches. Water at the rate of 50 M.G.D. shot 60 feet into the air for nearly two hours before cutoff could be completed. Fortunately the break was in an area where but small damage resulted.

With the accumulation of data as to frictional resistance to flow of materials and linings used in large conduits, most of the larger work is being designed on the basis of Hazen-Williams coefficients of from 140 to 150 for reinforced concrete pipe and 130 to 140 for bitumastic spun coating. In the 4 to 6-foot sizes this usually results in steel pipe being specified with a diameter approximately 2 inches to 3 inches larger than the internal diameter of concrete.

Some of the more important supply line work in progress illustrates the above.

LOS ANGELES AQUEDUCT

The largest supply line thus far under construction is the Los Angeles Aqueduct, 242 miles in length and over 12 feet in diameter. Considerable portions of this line are of precast reinforced concrete of the largest diameter yet built, namely, 12.67 feet and with heads up to 80 feet. Each 12-foot section of pipe weighs 43 tons necessitating the development of special machinery for casting, handling, transporting, and laying. These large pipes are supported on a concrete cradle which envelopes the lower portion of each section.

The magnitude of the Los Angeles Aqueduct problem necessitated unusual attention to the economics of design. The engineers of the Metropolitan Water District accordingly made unusually complete and detailed analyses of investment costs, and friction losses. Their studies in this regard are a marked contribution.

DENVER CONTRACT

At Denver, Colo., approximately 35 miles of conduits varying in size from 63-inch to 30-inch were designed and largely constructed during the past year. At Denver the practice was followed of preparing competitive specifications for welded steel with spun bitumastic lining and reinforced concrete. The steel stress in both types was fixed at 11,000 pounds per square inch. For the steel pipe $\frac{1}{16}$-inch additional thickness was allowed for corrosion. Steel pipe contained Dresser couplings at intervals varying with the diameter of the pipe. On the first contract of $13\frac{1}{2}$ miles of 42-inch, under heads varying from 100 to 325 feet, reinforced concrete pipe was the low bidder. In the next contract involving several miles largely of 54-inch and 63-inch pipe, steel was low. In the third contract, which consisted of approximately five miles of 54-inch pipe under heads varying from 150 to 400 feet, and which was routed a considerable distance through the congested section of the city, reinforced concrete was again low; and on the fourth contract, which involved some 10 miles of 42-inch, 30-inch and 24-inch pipe, for which the contractor could furnish for any one of the sizes either cast iron, steel, or reinforced concrete, the entire job was awarded to reinforced concrete.

Surge on the Denver lines is controlled by automatic cone valves

with double automatic relief valves designed to keep the surges from exceeding static head on the pipe lines. Automatic cone check valve protection is also provided where the pipe lines cross the Platte River and Cherry Creek. Automatic pressure control valves are provided to regulate the discharge of water from the new Moffatt tunnel filter plant into the high service areas in the city, or in case of water being available in excess of the high service demand, to bypass and regulate the discharge of the surplus into the low service reservoirs.

The City of New York has taken bids on the sinking of shafts in connection with an 85-mile tunnel which will be required on the Delaware river project. This is the start of a construction program estimated to take eight years and which will when completed, add approximately fifty percent to the present capacity of the New York water supply system.

During the past year Birmingham, Ala., has had under construction a large industrial water supply which includes the construction of an impounding reservoir storing 22 billion gallons, a 39 mile 60-inch welded steel pipe line, and many miles of smaller distributing lines. The financing of the construction was made possible by the signing of contracts by the industries for the purchase of sufficient water to guarantee payment of the bonds. The total cost of the work will be approximately $6,000,000. The project is now well over fifty percent completed.

The Fort Smith, Ark., supply line differs from the ordinary steel line in that the outside, after being coated with bitumastic preparation, is wrapped with unbonded 35 pound rag felt applied spirally and sealed at laps by a hot solution. The unbonded wrap is a development of the use of steel pipe in the oil fields which utilize it as a means of preventing the movement of the pipe in the soil from damaging the coating. The pipe slips through the wrapping in expansion and contraction and the coating is therefore not damaged. To facilitate slipping the pipe wrapping is coated on the inside with mica. This line has nine automatic reducing and control valves.

The Little Rock project includes a 32-mile 39-inch internal diameter reinforced concrete pipe line, carrying heads of from 0 to 300 feet. This pipe line is designed to operate on the hydraulic grade line, the regulation of pressure to prevent surcharge or water hammer being automatically controlled. The only valves on this line are at the two ends.

PUMPS

The most important development which it is hoped will materially improve the design of centrifugal pumps, is the monumental experimental work conducted by the Metropolitan Water District of Los Angeles and the staff of the California Institute of Technology. The Metropolitan District was confronted with the design of equipment which will ultimately handle 700,000 G.P.M. with a total pumping head of approximately 1,360 feet, which will require an electrical load of approximately 280,000 K.W. In addition to the structural features, the importance of efficiency may be visualized by the statement that a difference in efficiency of 1 percent would affect the power cost $40,000 per year. As a result of these investigations, it was found that the pumping head per stage could be as much as 440 feet or more without any sacrifice in efficiency, with inlet heads varying from 5 feet to 40 feet, and that single suction pumps could be used instead of the conventional double suction pumps. This reduction from two stages to one and from double suction to single was exceedingly important on the Los Angeles installation.

A second important contribution of this experimental work was the measurement of shaft deflections due to unbalanced radial forces which led to the design of unusually heavy shafting of rigid construction designed for the first time with an understanding of the stresses and deflections. It is possible that in this respect the experiments may have an important bearing upon future pump design.

Time permits of but a sketchy resume of the more important developments with reference to but a few of the larger projects illustrative of the advancements in progress. Much of the development is applicable to work regardless of size.

TWO-INCH CAST IRON PIPE*

By J. D. Sample

(*Executive Vice President, McWane Cast Iron Pipe Company*)

(*Birmingham, Alabama*)

We have long felt that the waterworks man had "sorrow enough in the natural way" without being plagued with any unnecessary pipe troubles. One of the very first things looking toward lightening your lives was to get together the figures on what really makes up the distribution system of the average water works. Regarding these, you will doubtless be as surprised as we to learn that, in twenty typical average water works systems in towns with populations between 1,000 and 250,000, *30 per cent—almost one third—is made up of two-inch pipe of some sort.*

This raised two questions: How long has this been going on and, what caused it?

Some individuals may disagree, but consensus of opinion seems to be that this shift to greater use of 2-inch pipe came in the early years of the present century and hand-in-hand with the development of low-cost transportation. Whether this was cause and effect or merely coincidence is something we may leave to the historians. But circumstantial evidence at least points strongly to the former. With the trolley car and the low-cost automobile came a change in American living habits, a shift to the suburbs and small outlying towns, and a change in the pipe sizes serving them.

Whatever the cause, water work men found themselves confronted with the fact of a change. Once cast iron pipe had meant big pipe. It did not enter the superintendent's or engineer's mind until the diameters being considered reached 4 inches and larger. Tracing this change, in the older days the need for and use of 2-inch pipe was small. This was because the cities which the older of us remember were compact. Lacking rapid means of getting about, our forefathers built up solidly. They had to live close in. Such cities spread

* Presented at the Buffalo convention, June 10, 1937.

upward instead of outward. Families lived in layers in flats or in city houses that were narrow and numerous to the block. This made for large water mains to serve these populous blocks. The place of small pipe in such a scheme was naturally quite limited.

Then came easier transportation. And certainly coincidental with it, if not because of it, everything was altered. The country took on new charms and new accessibility. Heads of families discovered they no longer had to live cooped up on crowded streets. They could still work in the city but they did not have to live in it.

Alert real estate developers saw their chance. Subdivisions sprang up everywhere about our cities. New suburban towns were born and boomed, laying a new demand upon the long-suffering water works men. For these new country dwellers wanted water—more water than ever. To the country habit of a bath every Saturday night they added the city one of baths on every other day in the week too! And they planted lawns, they raised gardens, they sprinkled both. Yet because of these very things they were spaced wide apart, they lived few to the block.

The old pipe sizes and layouts did not fit this new order. So what to do? For it would not pay from either present or future standpoints to lay large mains to serve these thinly-populated blocks.

To complicate this problem, America was also coming out of the mud with a rush—paving these suburban streets to accommodate the thousands of new automobiles that had made them possible in the first place. So the new pipe to serve the new era must be three things:

It must be small in diameter; It must be low in cost; It must be lasting in life. Digging up these new hard-surfaced streets to repair or replace pipe that might fail could no longer be looked on as a light matter.

Fortunately—and logically—supply developed in the face of this demand. Foundry developments brought the answer, an old material in a comparatively new size, 2-inch cast iron pipe.

It was large enough to serve, small enough to be economical, and permanent enough to protect the paving because it resisted corrosion. While certain developments in joints for it, to be mentioned later, added the elements of easy laying and of salvage value if larger sizes should be needed in its place in the future.

Of course certain questions and objection arose. "2-inch pipe for serving household consumption needs, yes," said some: "but

what about fire-protection? You can't feed fire hydrants with 2-inch mains."

And while some over-zealous real estate developers may have tried to do even that, we admit it is a fair question. But the answer is to run larger mains on one side of a street and two inch ones on the other. The streets, let us say, running east and west may be served with two-inch mains; and the avenues running north and south may have the larger ones for fire-protection purposes. In this way, no house is ever over a block from a large main or fire hydrant.

This is touching on the two-main system principle, of course. So we might enlarge it with one other thought: that the water-circulation advantages of the dual-main system may also be attained in places by connecting any larger dead-ends with a 2-inch pipe. Improved circulation at low cost and with permanence would follow.

Another common view of 2-inch mains has been that they are temporary; that an area will outgrow them before corrosion or other causes could enter the picture. In that case, the salvage-value of cast iron in any size steps in. And, with modern joints, 2-inch cast iron pipe comes up almost as easily as it went in. It can be used again elsewhere, as good as new. So, at worst, it may be re-laid elsewhere. At best it need never be touched again for repair or replacement.

For the privately-owned water company we would inject here another important point: when you use cast iron in any size you qualify for the low depreciation-rate arising from its long life, and THAT will be reflected in the rate-making base. It stays *up* with 2-inch cast iron mains, just as it does with 8-inch or 48-inch.

Adding all these items together, we find 2-inch cast iron pipe no longer beneath the true water works man's notice or dignity. Not when it is approximately 30 per cent of his typical system!

This makes it timely to discuss briefly here the progress in the pipe-maker's art in casting these modern small diameters. Yet your only interest in this modernization is in what it can do for you today that 2-inch cast iron pipe could not do for you yesterday, for various reasons. Now new improvements make possible new services and a new reliability. Because of the fact that you who use it have to live with this pipe after we have made it and you have laid it, you have some interest in why and how it has improved. Here, then, are some of the high-lights of why this small cast iron pipe is better than it could possibly have been only a few years ago.

In some foundries, 2-inch pipe is being cast mechanically now. That means cast uniformly, with precision, and from iron so scientifically chosen, mixed, melted, and poured that you find almost every resulting pipe exactly alike. Even the air of the cupola blasts these days is "weighted." Each size of pipe is cast from its own special "mix" of iron, especially designed for that particular diameter of pipe. Molds and cores for most 2-inch pipe are of "green" sand. Pipe so cast has a toughness, a resilience, that permits the famous "bending before breaking" tests which you have seen so frequently pictured.

Another point where the mechanical casting interests you is that it gives you pipe cast in longer lengths, hence fewer joints to the mile. Also the process lowers the cost to you, so that 2-inch cast iron pipe now meets the competition of other metals on a far more comparable basis than before.

But by competition we mean more than merely price. We mean the competition of convenience and service. Take tapping, for instance:—you can tap your 2-inch cast iron pipe up to one inch, not directly through the pipe wall but through the tapping collars cast at frequent intervals along each length. You can dig down to such a 2-inch pipe any time in the future to make a "wet" tap, and always find yourself near one of these collars, which are a thickening of the pipe wall in a ring all around it.

Or there is the matter of fittings. Bell and spigot fittings with lead joints factory-made in the pipe bells, ready to calk, are to be had. Or ordinary threaded fittings may be used. Either kind can be located exactly where desired in the line, just as with any other pipe.

For jointing the pipe in the trench there are two popular forms of joints. One is the bell and spigot factory-made just referred to; the other the over-sized male and female threaded. That is, 2½-inch female threads in the pipe bells, 2½-inch male threads on the spigots. Extra metal is cast where the threads are cut, so metal is not weakened, diameter is not constricted. When oversized threaded joints are used a flexible joint, however, should be inserted in the line every 36 to 90 feet.

These joints just described are easily protected, making it possible to stock 2-inch cast iron pipe in the open, the same as any other kind, for use as needed.

But small water mains are far from being the full field in which 2-inch and smaller cast iron pipe serves.

Notable among them is the use of this pipe for the underdrain laterals in water filters. The roster of American cities using many miles of such laterals is an impressive one. It includes Buffalo, Detroit, Philadelphia, Louisville, Richmond, Cleveland, Denver, Miami, Memphis, Minneapolis, Cincinnati, and a host of others. Of course, permanence is the idea foremost here, with economy a close second. Again, thousands upon thousands of feet of 2-inch cast iron pipe are growing old but not worn out now in the service of agitation lines in connection with sludge digestion in sewage disposal plants.

Another important place for small cast iron pipe is for services. Particularly to apartment houses and to small industries. The city of Los Angeles has made a very extensive use of cast iron services and a great many others resort to cast iron under paving to an important degree. The gas people are doing the same thing in many parts of the country, showing considerable partiality to the 1¼-inch cast iron pipe in their case.

Even golf plays a big part in cast iron pipe production now. With any future digging up of greens or fairways to repair or replace pipe counted all but a crime, hundreds of the newer courses, both municipal and private, have had their sprinkler systems installed with cast iron pipe, chiefly in the 1¼-, 2-, and 3-inch sizes.

By the same reasoning, parks, lawns, cemeteries, etc. have turned to cast iron pipe in small sizes for sprinklers.

The railroads are a whole story in themselves. You can well imagine their corrosion problem in the midst of cinders and filled ground about their yards and shops. Of late years they have met this with impressive footages of 2-inch cast iron pipe, not only for water but for low-pressure stream and compressed air service.

Summing up, 2-inch cast iron pipe appears to have earned its place in the sun, or in the ground, by meeting a new and definite need. It is both a part of the modern scene and an outgrowth of it. Fortunately, it is still an old product merely adapted to new uses. So that instead of introducing a new factor it was only necessary to extend an existing one. The old familiar cast iron pipe merely moved downward in size a few notches. Making it only necessary for the water works man to start his "cast iron thinking" at 1¼-inch instead of 4-inch. And, in so doing, to approach by a few more important steps his ancient ideal of "Cast iron for the *whole* water distribution system."

TREATMENT AND PURIFICATION OF WATER

PROGRESS AND DEVELOPMENTS DURING 1936*

By Paul Hansen

(*Greeley & Hansen, Chicago*)

STATISTICAL

During 1936 there were placed under construction or completed, approximately 226 water purification plants with a total nominal capacity of about 771,000,000 gallons per day. The range in individual capacity is from about one-tenth million gallons per day to about 280,000,000 gallons per day.

The plant having the largest capacity is the Spring Wells plant at Detroit. While this was finally completed in 1936, it had been in operation since 1933, and perhaps does not belong among last year's installations. The next largest plant is that still under construction at Milwaukee with a nominal capacity of 200,000,000 gallons per day. This is a compactly arranged plant with a number of interesting design and construction features. Among the former are two-story sedimentation basins similar to those in use at Fort Wayne, Indiana. The next largest plant is that at Denver with a capacity of 56,000,000 gallons per day. This plant is nearing completion. The largest plant to be completed and placed in operation is that at Hammond, Indiana, with a nominal capacity of 20,000,000 gallons per day.

Of the works placed under construction or completed during the past year about 131 were built primarily for purifying the water. Eleven of these are used for softening also. Ninety-seven installations are for improvement of mineral content of the water such as softening, iron and manganese removal, and the removal of carbon dioxide or for some combination of these purposes.

Table 1 gives a compilation of these statistics.

P.W.A. records, kindly furnished by Col. Horatio B. Hackett, Assistant Administrative P.W.A., indicate that more water works

* Presented at the Buffalo convention June 10, 1937.

projects were started in 1936 than during any year since the beginning of the depression, but the total cost of the projects started in 1936 was less than the total cost of those started in 1934 and 1935, respectively. The figures available make no separation between

TABLE 1

Summary of water purification works started or completed during 1936

PURPOSE OF TREATMENT	NUMBER OF PLANTS	PER-CENT TOTAL PLANTS	CAPACITY, M.G.D.	PER-CENT TOTAL CAPACITY	POPULATION SERVED	PER-CENT TOTAL POPULATION
Purification only	119	53	657.186	85	2,792,996	83.1
Iron removal only	38	17	8.771	1	49,584	1.4
CO_2 removal only	7	3	0.910	0.1	5,624	0.2
Softening only	28	12	66.510	9	266,085	7.9
Purification & iron removal	1	1	0.500	0.1	2,523	0.1
Purification & softening	9	4	21.522	3	132,058	3.9
Purification, iron removal & softening	2	1	1.800	0.2	11,893	0.4
Iron removal & softening	16	7	8.870	1	76,541	2.3
Iron removal & CO_2 removal	2	1	3.100	0.4	22,830	0.7
Iron & manganese removal & softening	1	1	1.500	0.2	1,679	
Total plants	226		770.69		3,361,813	

TABLE 2

Water works construction under P.W.A. compared 1933 to 1936

YEAR	NUMBER OF PROJECTS STARTED	VALUE OF CONTRACTS AWARDED
1933 (6 months)	47	$7,400,000
1934	419	45,700,000
1935	452	54,000,000
1936	551	40,100,000

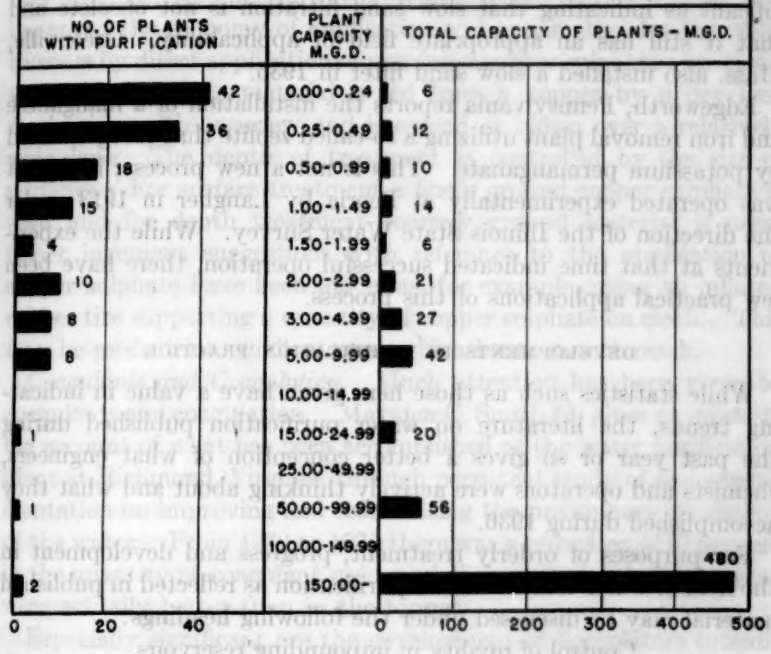
purification plants and other water works facilities. They are given in table 2 as an indication of trends.

No attempt has been made to obtain a list of new chlorine installations but figures from manufacturers indicate that these are in the neighborhood of 300. This does not include a number of water works using hypochlorites.

Comparatively little information could be readily obtained regard-

ing the costs of water purification works. Furthermore, it is difficult to make direct comparison of costs because all of the items included are not known. For example, some costs include low lift pumping stations and others do not. Installation costs of treatment works proper, exclusive of pumping stations, range from about $22,000 per million gallons nominal capacity for large plants to as

FIGURE 1
NUMBER AND COMBINED CAPACITY OF PURIFICATION WORKS WITHIN CERTAIN CAPACITY RANGES STARTED OR COMPLETED IN 1936



high as about $80,000 per million gallons capacity for small plants. The highest figure mentioned represents costs on a W.P.A. project.

The bare statistics such as have been obtainable from State Departments of Health throw comparatively little light on the technical advances in the art of water purification during 1936. However, a few notations that have been received are significant as to trends.

Bristol, Connecticut reports the installation of a filter plant constructed of steel, similar to that at Burnt Mills, Maryland, which evidences the fact that this type of construction is attracting attention in other parts of the country.

Lebanon, Kentucky, reports the installation of a new plant using "Anthrafilt" (trade name for crushed and graded anthracite coal) as a filtering medium. As will be observed later, this or similar material is being used at a number of places throughout the country.

At South Fallsburg, New York, an unusual plant, primarily for taste removal, was installed comprising pressure filters, and pressure activated carbon units without flocculation or sedimentation.

Slow sand filter plants were reported as being installed at Palmyra, New York, Northborough, Mass., and Russel, Mass. This is significant as indicating that slow sand filtration is not obsolete and that it still has an appropriate field of applicability. Greenville, Mass. also installed a slow sand filter in 1935.

Edgeworth, Pennsylvania reports the installation of a manganese and iron removal plant utilizing a so-called zeolite that is regenerated by potassium permanganate. This is not a new process; in fact it was operated experimentally at Peoria by Langlier in 1913 under the direction of the Illinois State Water Survey. While the experiments at that time indicated successful operation, there have been few practical applications of this process.

DEVELOPMENTS IN PURIFICATION PRACTICE

While statistics such as those here given have a value in indicating trends, the literature on water purification published during the past year or so gives a better conception of what engineers, chemists and operators were actively thinking about and what they accomplished during 1936.

For purposes of orderly treatment, progress and development in the field of water treatment and purification as reflected in published material may be discussed under the following headings:

Control of quality in impounding reservoirs
Coagulants and coagulation
Sterilizing agents and sterilization
Taste and odor removal
Sedimentation
Filters
Softening
Manganese and iron removal
Fluorides and their removal
Control of quality in distribution system
Laboratory control
Automatic operation

It is significant that the great majority of contributions to the literature on these subjects have been made by members of the American Water Works Association, indicating that the Association is the heart and mind of the water works industry.

Control of Quality in Impounding Reservoirs. A trend is discernible to give considerable attention to improved methods of applying copper sulphate to impounded waters. This is a reflection of higher standards with reference to correction of tastes and odors. Treatment of large reservoirs is relatively expensive. Goudey, (1) Sanitary Engineer for the Bureau of Water Works of Los Angeles, has improved the economy of application and apparently also the effectiveness by direct application of powdered copper sulphate over reservoir surfaces. The material is fed from a hopper by a dry feed mechanism with accuracy and is spread or blown over a relatively wide lane. The depth of treatment is controlled by the size of particles. For surface treatment a finely ground copper sulphate is used and for depth treatment coarsely ground material is used. Other ingenious suggestions with reference to the application of copper sulphate have been made, as, for example, using an inflated rubber tire supporting a quantity of copper sulphate on cloth. This may be pushed into shallow areas which boats cannot reach.

Coagulants and Coagulation. Much attention has been given to coagulants and coagulation. Marsden C. Smith (2) gives an interesting account of what has been accomplished at the water purification plant at Richmond, Virginia, through persistent study of and experimentation on improving and economizing the preliminary treatment of the water. From 1930 to 1935 there was a reduction of 67 percent in the quantity of coagulant used, and the results in the latter year were actually better than in the former.

Especially significant are the development of flocculators in sedimentation basins and the judicious use of two coagulants, namely, alum and chlorinated copperas. Alum appears to be the more economical in warm weather and chlorinated copperas more economical in cold weather.

The coagulants are also used in combination. Sometimes alum in small quantities aids the chlorinated copperas, and at other times chlorinated copperas in small quantities aids alum. The aiding chemical is usually used in the proportion of 10 to 15 percent of the main coagulant.

Smith also speaks of the importance of accuracy in the application

of coagulants to obtain good results, especially at low temperatures and with descending turbidity. Either too much or too little coagulant may give poor results. This same phenomenon was pointed out to the writer verbally by Arthur F. Mellen, in charge of purification at Minneapolis. Experience at Richmond indicates that small quantities of lime tend to widen the range in the quantity of coagulants that will produce effective coagulation.

Kunz, (3) chemist of the Water Department, Emporia, Kansas reports better results and better economy with ferric chloride as compared with other coagulants. Bean (4) at Providence, after experience with many coagulants, found ferric sulphate the most satisfactory. More recently ferric chloride in combination with lime has been adopted.

The search for more accurate and reliable chemical feeding devices is reflected in an article by Fitzgerald (5) describing his experiences with the dry feeding of chemicals at the Norfolk, Virginia water works. The article reflects growing interest in the electro-magnetic pulsator as a means of chemical feed regulation. In another article Hartung (6) offers some excellent suggestions for specifications in purchasing lime slaking equipment.

Leipold (7) superintendent of filtration at Winnetka, Illinois, has called attention to the importance of effectively dissolving the coagulant before it is applied to the water to be treated as a means of obtaining better coagulation. He conducted a series of experiments to ascertain how best the chemical might be effectively dissolved. He demonstrated that a larger dissolving box is required than ordinarily provided with commercial machines and that solution can be promoted by vigorously stirring the water in the dissolving box with a propeller. The same observation was made by Gale at Michigan City, and the effectiveness of coagulation was improved at the Michigan City plant by equipping the dissolving boxes with rapidly revolving propellers. At Hammond large dissolving boxes equipped with stirring devices were included with the original installation.

The most important suggestion of the year, and perhaps one which may materially modify coagulation practice, is the proposal by Baylis (8) that sodium silicate be used in conjunction with other coagulants to promote coagulation. The discovery of the effectiveness of silicates in aiding coagulation resulted from failure to get effective coagulation when using distilled water. This started a

search for ingredients in natural waters which seemed to aid coagulation. Persistent effort revealed the part played by silicates. In the development of the application of silicates to improve coagulation it appears that sodium silicate in the ratio of 40 percent of the coagulant used produces rapid and effective coagulation. To obtain satisfactory results it appears necessary to make an adjustment with sulphuric acid.

A newcomer in the field of coagulants is Bentonite. This is a natural clay or marl having peculiar colloidal properties. It is found in natural deposits in Utah. Experiments by Olin and Peterson (9) indicate highly effective coagulation in the treatment of water. However, the merits of this substance have not yet been worked out with reference to effectiveness and economy on a plant scale. The material has sufficient promise, however, to warrant its careful investigation.

Slocum of the General Reduction Company, Macon, Georgia, is advocating the use of absorbent clays for water coagulation. At Atlanta, Georgia, Paul Weir has used about 17 pounds per million gallons of this clay along with other coagulants for a year and a half and reports that it produces a more sparkling effluent than can be obtained by any chemicals or combination of chemicals. It is claimed that the clay has no action on the chlorine that may be applied to the raw water. On the contrary, the chlorine appears to be held in the surface of the coagulated masses and maintains the deposited sludge in fresh condition.

Hoskinson (10) Chief Engineer, Division of Water, of Sacramento, California, gives a good review of the development of mixing practice to aid coagulation. He does not, however, mention that mixing by means of stirring devices was used at Algiers, Louisiana, as early as 1911. However, the scientific accuracy of the work of Langelier at Sacramento in 1919 attracted widespread attention. Writers generally agree that an effective mixing of coagulants with the raw water is the first essential, and gentle prolonged mixing therafter is the second essential to effective coagulation. There is a disposition to refer to the first mixing period as "flash mixing."

Billings (11) Superintendent and Chief Chemist of the water works of Dallas, Texas, gives an interesting review of the varied problems met with in coagulation practice. At the new Bachman plant at Dallas, after various trials, he has come to the conclusion that normally lime and chlorinated copperas represents a definite economy as

compared with the use of lime and copperas alone, or as compared with chlorinated copperas alone. He finds it advantageous to use alum as a secondary coagulant before the water passes on to the filters. The secondary coagulation he believes would not be necessary if the floc were not broken up by relatively long channels extending from the coagulation basins to the filters.

Billings finds that different waters behave so differently with reference to coagulation that he believes that economies would be effected if a pilot plant were first constructed and operated before preparing the designs for the main plant. He also urges that flexibility be incorporated in the design to permit the operator as much variation in the treatment as possible to meet changing conditions in the water to be handled.

Sterilization and Sterlizing Agents. Chlorine is still considered by water works men as the outstanding sterilizing agent. Its use has been extended to include not merely bacterial sterilization, but also the removal of other organisms. It is often used with or without copper sulphate for controlling algal growths. It is more and more being used in conjunction with ammonia to form chloramines. This not only avoids chlorinous tastes but produces a sterilizing agent which has continuing effect through the distribution system.

Renewed interest is evidenced in the use of excess chlorine for taste and odor control. The use of excess chlorination followed by de-chlorination as practiced by Howard at Toronto is well known. The renewed interest in excess chlorination has been brought about by the necessity of using large and costly doses of activated carbon for adequate taste and odor control. By using excess chlorine in conjunction with activated carbon the net cost of odor control may be reduced. Chloramines may also be used in this connection.

Excess chlorine has also been proposed for bleaching a water. Howard of Toronto has reported some favorable results. A colored water used by a paper mill at Rhinelander, Wisconsin, has been effectively bleached with large quantities of chlorine, perhaps too great for use in municipal practice. Chlorine may also be used as an oxidizing agent for removal of iron, as proposed by Weston for a small water works in Massachusetts.

Much of the literature relating to chlorine has to do primarily with its more accurate and effective control. Cox (12) has given an excellent summary of experiences with the ortho-tolidin test for the determination of residual chlorine and has made clear the nature

of and the methods of guarding against interferences with this test by manganese and nitrates.

Water purification plant operators appreciate the frequent and often rapid variation in chlorine demand of a given water, and accordingly much interest is evidenced in experience with automatic control of chlorine application at Los Angeles where for several years chlorine has been successfully applied by machines which are actuated both by the rate of flow and the residual chlorine. The residual chlorine is registered by photo electric cells which in turn adjust the application. Experiences with this equipment are described by Goudey (13).

Ammonia also comes in for uses other than in connection with sterilization. For example, at Atlantic City it is used to prevent the oxidation of ferric iron by the chlorine, and it is reported to have been used in Canada for raising the pH value of water to prevent corrosive action. In this case, however, the acidity of the water is not due to carbon dioxide but to sulphuric acid fumes from nearby refineries.

With the use of large quantities of chlorine and ammonia, as for example at Chicago, attention is called to certain dangerous characteristics of these chemicals. Gerstein (14) Chemist for the water safety control department of Chicago, discusses the hazards in handling both chlorine and ammonia. He points out that phosgene, a poisonous gas used extensively in the World War, is formed by carbon monoxide and chlorine. In one of the Chicago pumping stations phosgene was formed by leakage of carbon monoxide into the tunnel shafts where chlorine was being applied. Chlorine and ammonia mixed in the atmosphere or in concentrated solutions forms nitrogen tetrachloride, which is highly explosive. Ammonia mixed with five parts of air may be ignited by sparks or high temperatures. Neither chlorine or ammonia should be stored near radiators. Large chlorine containers and high capacity chlorinators, such as have recently become available, greatly reduce the number of valves and connections and hence reduce the leakage danger. Gerstein also recommends that in all instances separate rooms be provided for the containers and the feed machines. Many other practical suggestions are offered.

While chlorine, with or without ammonia, is generally accepted as the most economical and efficient sterilizing agent, water works men are nevertheless interested in other sterilizing agents. During

the past year much attention has been given to the use of colloidal silver for sterilization. Gallaher (15) conducted a series of experiments on the germicidal effect of "Super-Ionite." He used a small drinking water system comprising a stone filter, a Super-Ionite compartment, and a reservoir for treated water. Super-Ionite is a synthetic granular material made up of silver in combination with a base exchange silicate. A period of storage of treated water seems to be more or less essential for effective sterilization. He concludes that this sterilizing agent may be used to effectively sterilize a water that requires sterilization only, such as relatively clear waters. He points out that the removal of the colon bacillus is effective but the removal of total bacteria is erratic. He does not, however, go into the question of cost when used on a large scale.

Another interesting paper on sterilization with silver is that of Just and Szniolis (16). They found that silver is effective and that it has a continuing effect on the water mains. They, however, caution against the possibility of argilosis (silver poisoning) but feel that silver can be safely used on expeditions, in war time, and perhaps for swimming pools.

A valuable contribution on silver sterilization is that of Shapiro and Hale (17). This comprises a thorough investigation of the effectiveness of Katydyn, a silver compound, in the treatment of the swimming pool water. They found, as did Gallaher, that the removal of the colon bacillus was effective, but that the percentage removal of total bacteria was relatively low. The silver produced a turbidity in the pool that was objectionable and even dangerous in that it might obscure a drowning person in the deep portion of the pool. The cost of this treatment was much higher than treatment with chlorine and ammonia. The possibility of argilosis was also pointed out.

Taste and Odor Removal. Removing tastes and odors is probably uppermost in the minds of water works men. The main contributing factors to the maintenance of this interest appear to be: first, a growing public demand for a tasteless and odorless water; second, realization on the part of operators that taste and odor can be definitely removed with sufficient quantities of activated carbon; and third, a better understanding of the technique of measuring the intensity of odors and their removal.

Activated carbon is the outstanding chemical used in the removal of tastes and odors. The most significant contribution to the sub-

ject of tastes and odors is that by Baylis and Gullans (18) on an improved odor test. This describes a means for determining and recording quantitatively odors so slight that a water consumer would not notice them. In fact, the paper places much emphasis on the necessity of the operator in charge of water purification being able to detect odors before they are observed by the consumers. The determination does not, of course, have scientific accuracy, inasmuch as it is made with the nose and it is inevitable that different observers would record different results. Nevertheless, by applying the procedure carefully as outlined, reasonably concordant results are obtained. The essentials of the determination are a carefully fitted nose piece to be inserted in a flask containing a definite quantity of the water and a definite quantity of air heated to a definite temperature.

As already suggested, other substances than activated carbon for removal of tastes and odors have a claim for consideration, as, for example, excess chlorination, ozonization, aeration, etc. Gullans (19) Senior Sanitary Chemist, Division of Water Purification, Chicago, makes an interesting comparison of results obtained in odor removal, including—(1) coagulation and filtration, (2) activated carbon, (3) super-chlorination with de-chlorination, (4) ozone, (5) chlorination with ammoniazation, and (6) aeration. The experiments were made on Lake Michigan water. For this water the results indicated clearly that activated carbon is most effective and that practically complete removal of taste and odor may be had by applying an adequate quantity of carbon. Gullans, however, makes it plain that the results were not intended to indicate the relative efficacy of the different methods for all waters under all conditions. It would have been interesting had Gullans tried a combination of excess chlorination and activated carbon with reference to economy.

During the year increased interest has been shown in granular activated carbon units or filters. Harnish (20) gives some interesting experiences and operating costs on a small installation at Culver City, California. This installation treated a ground water infected with taste-producing organisms. The estimated cost for carbon is about $3.10 per million gallons treated. Harnish describes clogging troubles primarily due to neglect and the manner in which they were overcome by treatment with caustic soda followed by treatment with weak hydrochloric acid. The introduction of air wash was also helpful in keeping the material clean.

The South Fallsburg installation of a carbon unit is described by Schinman (21). This plant comprises treatment of a surface water in a pressure filter followed by a carbon unit. Chlorine is used as a sterilizing agent and the chlorinous taste is also removed by the carbon unit. The installation is for a small resort town having but a few hundred people in winter and about 5,000 people in summer. This is said to be an economical and adequate solution for the local problem.

The largest installation of granulated carbon units is at Oshkosh, Wisconsin, described by Howson (22). Carbon units are also embodied in the new water purification works for Neenah, Wisconsin.

Sedimentation. Sedimentation has not been neglected but it has been relatively little discussed as compared with other factors relating to water purification. Proper sedimentation is a subject that is far from being solved scientifically and adequately. Nevertheless, in practical experience reasonably good results are obtained with sedimentation tanks of various designs. A number of plants have found that vertical baffles across a sedimentation basin at intervals is effective in checking short circuiting and improving sedimentation. These baffles are carried from the bottom of the basin up to a level several feet below the water surface. Generally speaking, an observant and energetic superintendent can with comparatively little difficulty and expense adjust defects in an existing basin by means of various forms of baffles, inlet and outlet controls, guide vanes, and the like, all constructed of wood. It is not intended to suggest that the subject of sedimentation is unimportant. On the contrary, it merits much more study and research.

Sedimentation bears a close relation to coagulants and coagulation, and relatively speaking, coagulants and coagulation are probably more significant than sedimentation. For example, if quick and effective coagulation is obtained, a short period of sedimentation—say of two hours, may be sufficient, whereas if poor coagulation is obtained a prolonged period of sedimentation of as much as eight hours may not be satisfactory. All operators are agreed that effective coagulation and sedimentation is important and that ample sedimentation is a purification plant's best balancing element.

Filters and Filtration. It is impossible to point to anything definitely new with reference to the design, operation, or maintenance of filters. Active discussion still centers on the best method of keeping

the filter sand clean. A searching analysis of this problem has been contributed by Baylis (23). This paper reviews the theory and experience with reference to the behavior of sand and gravel beds, including mud ball troubles, cracking, shifting of the sand and gravel, etc. The paper is primarily an effective argument in favor of supplementary surface wash. Water works designers are now accepting the efficacy of surface wash. The method was first advanced by Pearse and Deberard (24) in Oakland, California, as early as 1908. It has now been revived by Baylis in a convincing manner. It has already been adopted by Kenosha and Racine, Wisconsin and Grand Island, New York. The equivalent of a surface wash has been used at Kenilworth, Illinois. This arrangement comprises sub-surface cones surrounded by screens to increase filtering area. To keep the cones clean they are back-washed and they have proven quite as effective as a means of keeping the sand clean as they have in increasing filter capacity. A similar arrangement was tried experimentally at Toledo.

Two of the filters at Winnetka, Illinois and most of the filters at Waukegan, Illinois have been provided with a surface wash. These surface washing devices consist simply of four jets arranged at the center of the filter near the surface of the expanded sand. The jets are directed horizontally toward each of the four corners of the filters. The arrangement was devised by James Ashworth, Superintendent of Water Works at Waukegan, Illinois. At Hammond the piping arrangements are such that surface wash may be readily installed at any time that it is needed. Limited funds prevented its use with the original installation.

Renewed interest is exhibited in filter bottoms. So-called Wheeler bottoms have been installed at Springfield, Illinois and at Rocky Mount, North Carolina (25).

DeCosta (26) describes so-called "egg crate" bottoms as used in California. These crates are made of wood and comprise square compartments extending from the bottom of the filter up to the top surface of the gravel. They are reported as being effective in preventing shifting of the gravel bed notwithstanding uneven application of wash water.

With reference to efficient washing and control of growths and mud balls in the sand, Krum at Allentown, Pa. reports that he is able to keep the filters in excellent condition by applying 1700 pounds

of chlorine per million gallons to the wash water. This does not result in a taste in the filtered water but on the contrary decreases the taste by destroying the organic matter in the filters.

Filter underdrains made of porous blocks of carborundum or other similar material are attracting interest but have thus far not been used extensively in practice. Ripple (27) discussed the use of porous plates in one of the old filter plants which treats a portion of the water supply of Denver. He reports experiences of 9 months and indicates satisfactory results. He emphasizes, however, the necessity of obtaining good filtration so that no coagulant or turbidity reaches the underdrain plates. The underdrains may be cleaned by suitable treatment with caustic soda. In this connection they have an advantage in that they are used without a gravel bed; hence the removal of the filtering material is simplified. There appears to be no weakening of the joints which hold the porous plates in place.

Reassuring experience with porous plate underdrains has been had at Grand Rapids, Michigan. Harry Campion reports the use of such underdrains first experimentally on a small scale for six months, and later for fourteen months in one of the regular filters. Though the water applied to the filters sometimes contain caustic alkalinity there has been no serious clogging.

Renewed interest has been shown in the use of crushed anthracite as a filtering medium. Ripple (28) discusses the use, for a ten-year period, of crushed anthracite resting on top of sand at the Marston Lake filter plant of the Denver Water Works. He favors the use of anthracite because its lower specific gravity causes it to expand more than sand with a given rate of wash water, and hence cleanses more readily. He finds that it eliminates mud ball and cracking troubles and that there is small tendency for the medium to become coated.

Another interesting contribution was made by McCurdy (29). This paper describes the results obtained over a period of 5 to 8 months with two filter plants. In each filter plant one of the filters was filled with crushed anthracite and the results obtained are compared with adjoining filters operating under identical conditions but filled with sand. There seems to be little difference between the performance of sand and anthracite. The anthracite grains are somewhat coarser than the sand and this apparently results in longer filter runs. The bacterial results are somewhat but not substantially better with sand than with anthracite. More chlorine

passes through the sand filters than through the anthracite, hence the residual when using sand can be maintained with somewhat less chlorine. The removal of turbidity and color are substantially the same for both anthracite and sand. These plants are still under observation. Time may reveal conditions and performance not now apparent. McCurdy emphasizes the fact that the raw water was relatively pure and comparatively easy to treat and that the water was well prepared before reaching the filters so that the turbidity of the applied water was but 2 parts per million. Accordingly neither the sand nor the anthracite operates under severe conditions.

During the past year as in some previous years there has been an inclination to use coarser filter sand with an effective size of as much as 0.6 millimeters. Little appears in the literature of the past year with reference to the relative merits of different sizes, though McCurdy makes mention of the fact that the effective size of the anthracite grains are 0.7 millimeters, whereas the effective size of the filter sand is but 0.38 millimeters; yet these differences in sizes do not seem to have any effect on the removal of turbidity. Spaulding at Springfield reports satisfactory results with an encrusted sand having an effective size of 1.0 millimeter and with double the normal rate of filtration.

An interesting departure from standard filter practice in treating water supplies is that of Portland, Maine. Fuller (30) Chief Engineer of the Portland Water District, reports the raw water of excellent quality, both physical and sanitary, but occasionally algae growths develop. A Magnetite filter similar to that used in sewage disposal practice has been installed to remove these algae. Sufficient experience has not yet been had to determine the efficacy of the installation.

Softening. As evidenced by statistical information, water softening of municipal water supplies has advanced substantially. However, during the past year comparatively little space in water works literature has been devoted to the subject of softening. This may be in part due to the fact that most of the new plants embodying softening are relatively small in size and have not been written up. Furthermore, a number of the small plants have used commercial zeolite softeners. These commercial softeners have been developed to a high degree so that they are practically automatic.

Stanley (31) gives an interesting analysis of the relative merits and relative costs of zeolite softening as compared with lime and soda softening for a small municipal installation. He arrives at the

conclusion that under local conditions zeolite treatment will prove cheaper and substantially more convenient.

An outstanding new plant employing water softening is that at Springfield, Illinois. As a result of experience with an existing water softening and iron removal plant, Charles H. Spaulding, Superintendent of Utilities of Springfield, has made some marked departures from usual water softening practice. The new plant is also used for purification of water obtained from a newly formed impounding reservoir of large size. The water is treated with alum, activated carbon and lime. Removal of the non-carbonate hardness is not attempted.

The preliminary treatment takes place in mixing and sedimentation chambers called "precipitators" of a design developed by Spaulding. Each unit comprises a central truncated cone with the small end upward and the large end downward, and outside of this is another truncated cone with the small end downward and large end upward. An annular V-shaped space is formed between the two cones at the bottom of which is a slot. The inner cone constitutes the mixing chamber. It is provided with mechanical stirring devices that keep the water well but not violently mixed with the chemicals for a period of about 30 minutes based on nominal capacity. After mixing, the water emerges through the slot at the bottom of the V-shaped annular space between the inner and outer cone and rises slowly to a peripheral overflow trough at the top of the outer cone, during which rise sedimentation takes place. The sedimentation period is one hour, based upon the nominal capacity of the plant. Sedimentation is not effective, however, until there is formed a sludge cloud above the slot. The particles in the sludge cloud apparently act as adsorbent media. The sludge is drawn off slowly and more or less continuously. Provision is made for recarbonation of the settled effluent but Spaulding states that this has not been necessary inasmuch as the sedimentation process effectively removes non-carbonates above the point of saturation.

Spaulding also dewaters lime sludge on large sludge drying beds and finds no difficulty in having it removed for use on farm lands. Campion at Grand Rapids successfully dewatered lime and alum sludge experimentally on a small vacuum filter, but did not feel that the cost was warranted unless a reasonable market for the sale of the sludge cake could be developed. Baylis has recently begun tests on dewatering filter plant sludge with vacuum filters. The

method has applicability where large quantities of sludge are difficult to dispose of because of lack of an adequate water way to carry them off or because of lack of land for sludge drying beds.

Iron and Manganese Removal. Year by year manganese is becoming more and more conspicuous in water purification practice. Probably this is partly due to a better knowledge of how to deal with manganese, and partly due to increasing standards of water quality which cause the consuming public to be intolerant of manganese effects which were formerly regarded as negligible. Experience in the removal of manganese at Providence has attracted attention in recent years. Its presence developed some interesting technique in pH conditioning and coagulation.

Willcomb (32) Superintendent of Filtration at Albany, New York, gives an excellent review of the knowledge and theories regarding manganese in water and an interesting account of a practical approach to the removal of manganese at Albany from the new Albany water supply. It is interesting to note that he found aeration, lime and alum reasonably effective. This treatment has also been found effective at Wausau, Wisconsin, as applied to well water. Willcomb describes some preliminary small scale experiments in which lime and copperas was used. This proved effective in removing the manganese but Willcomb reports a sweetish taste in the filter effluent which he thought would be found objectionable by the consumers. This is an unusual experience and it would have been interesting to conduct the experiment longer and with different chemical doses with a view to ascertaining the cause of the sweetish taste. The increase of the iron content in the treated water during the experiments with lime and copperas is also unusual and suggests that this, too, might have been overcome by proper adjustments.

One of the most important installations for the removal of iron and manganese is at Lincoln, Nebraska, described by Ericson (33) City Engineer. The plant consists of aeration, chlorination, upward flow through gravel contact beds, two hours' sedimentation, and final sand filtration. The effectiveness in removing manganese increased with the coating of the gravel in the contact bed and the sand in the filters.

At Ambridge, Pa., manganese is removed with zeolite as described by Davis and Campbell (34).

A paper of unusual significance relative to iron removal is that of Hale (35). The skill with which the investigation was conducted

is quite as noteworthy as the results obtained. Hale found that a water treated with lime to remove carbon dioxide and with pH adjusted to about 8.0, would effectively remove iron without aeration. Moreover, water so treated contains no carbon dioxide and no oxygen and hence is noncorrosive. The iron is removed in the form of insoluble ferrous carbonate in a closed system. The filters are cleared of precipitated calcium carbonate by treatment with water directly from the well. Due to the high carbonic acid content of the raw well water it requires only a relatively small proportion of the volume of water treated to remove calcium carbonate from the filtering medium.

Fluorides in Water and Their Removal. During the past year the presence of fluorides in water has commanded attention. Their presence is much wider spread than hitherto supposed. This has been brought about by examination of many well waters in Wisconsin and in Ohio for the presence of fluorides. Subsequent examinations of children's teeth in the localities where fluorides are present indicated that fluorosis or mottled enamel was also present. Blohm (36) describes a damage suit against Chetopa, Kansas because of fluorides in the public water supply. The suit claims not only injury to a girl's teeth, but also injury to the bone structure which resulted in incapacitation.

Sanchis (37) reviews methods of testing for fluorine and fluorides in water. He indicates that students generally agree that one part per million of fluorides is the maximum permissible to avoid fluorosis. The effect of fluorine seems to depend upon it's combination. Generally soluble forms in organic matter are the most harmful. He indicated that no practicable treatment for the removal of fluorine had yet been developed.

Fink and Lindsey (38) described the experimental use of specially prepared activated alumina as a means of reducing fluorides in water. They pointed out that regeneration of the alumina is possible but not practical. The efficiency and capacity of the process depends on the pH, also the lowest pH within the potable range gives the best results. They also considered treatment with lime and metallic magnesium but found this much less effective in the removal of fluorides than treatment with the activated alumina.

Scott, Kimberly, Van Horn, Ey and Waring (39) have made the most encouraging contribution on the removal of fluorides that has thus far appeared. They describe a practicable and low cost process

for the removal of fluorides. It is based upon the observation that fluorides are removed in connection with softening of water with lime and soda, especially when the water being treated is high in magnesium. Experimentation indicated that the amount of fluoride removed is in the approximate amount of 7 per cent of the square root of the magnesium removed. If enough magnesium is not present in the water naturally, it may be added in the form of magnesium sulphate (epsom salts). The process seems to be economically practicable when fluorides do not exceed 3½ parts per million. Ordinarily the fluoride content of Ohio waters is less than this. The authors make some illustrative computations of costs and show that to reduce fluorides from 2 parts per million to 1 part per million in a water containing naturally 36 parts of magnesium per million will cost about 2.43 cents per thousand gallons above the ordinary cost of softening by the lime and soda processes. With the same water, to reduce the fluorides from 2.5 parts per million costs about 6 cents above softening costs per thousand gallons. With larger quantities of fluoride the cost increases rapidly and soon become prohibitive for municipal purposes. The cost also increased with decrease in the magnesium naturally in the water. The authors estimate that the installation cost for a plant suitable for serving a population of 1000 people is about $10,000.

Control of Quality of Water in Distribution System. Marked progress has been made in a better understanding of the development and control of objectionable characteristics of water in the distribution system. The best summary of the subject is given by Howard (40). The deterioration of quality of water in the mains relates not only to possible contamination from cross connections, but from other causes as well, such as chemical changes, growths of bacteria and other organisms, entrance of worms and turbidity from open reservoirs, etc. The matter of correction for corrosion has been discussed more than any other phase of this subject and it has been viewed primarily from the chemical standpoint.

Langelier (41) undertakes to give a better understanding of the conditions that cause encrustation and corrosion and gives a practicable method of calculating the so-called "saturation index" of calcium carbonate. This index is the pH value of the water less the calculated pH value at which the water is in equilibrium, that is to say neither over nor under-saturated with calcium carbonate. He calls this pH value pH_s and works out a formula for its calculation

based upon determinations for calcium, alkalinity as calcium carbonate and total dissolved solids. He gives tables to facilitate this calculation. A negative saturation index at any given temperature indicates corrosive qualities and a positive index indicates encrusting qualities.

McLaughlin (42) Sanitary Engineer of the West Virginia Water Works Company, describes laboratory tests of a relatively simple character for determining the pH at which a given water is in equilibrium. This is done by treating the water with calcium carbonate. The procedure adopted assumes that the degree of supersaturation of the water at a given alkalinity and pH value is a function of the degree of increase or degree of decrease in the total alkalinity of the water after contact with an excess of pure calcium carbonate. Therefore to determine the pH value at which the saturation point of the undersaturated water is obtained, it is only necessary to increase the pH of the sample of that water with lime through a series of cut and try pH values then determine the degree of under-saturation or over-saturation as expressed in parts per million gain or loss in the total alkalinity after treatment with an excess of pure calcium carbonate. By means of a graph for plotting the differences in alkalinities against their corresponding pH values, the increases or decreases in alkalinity are shown as ordinates and the pH values as abscissa. The point where the curve drawn through the several pH values intersects the neutral ordinate marks the pH value of the calcium carbonate saturation point of the samples tested. By repeating this process for waters of different initial alkalinities it is possible to plot the series of pH values for calcium carbonate saturation points corresponding to these alkalinities. Thus with a known alkalinity the desired pH can be selected from the chart and treatment can be applied accordingly. Temperature variations should be considered but under ordinary circumstances these are not very important.

Doubt is cast on theories of what constitutes a corrosive water by a series of experiments by Hoover (43). Experiments on galvanized iron hot water tanks such as are commonly used in dwelling houses seem to contradict the theory that higher pH values prevent correction, or that corrosive action depends on oxygen content. These studies are not yet complete nor does Hoover state any conclusions as final. They are being continued and results will be awaited with great interest.

According to Hutton (44), extensive efforts have been made to

correct corrosion in water systems along the Atlantic seaboard. In this connection there has been used lime, caustic soda and sodium carbonate. He reviews a number of these efforts to correct corrosion and gives various statistics relative thereto. He emphasizes, as do Reddick and Lindeman, the view that pipe tuberculation is due to biological action and mentions a number of places where carrying capacity of mains has been increased and red water troubles stopped by maintaining a residual of choramines in the distribution system.

One of the most convincing examples of prevention of tuberculation in pipe lines by chloramine treatment is described by Ackerman (45) General Superintendent, Consolidated Water Company, Utica, N. Y. A 12-mile pipe line was frequently cleaned and each time was followed by rapid tuberculation. At times the value of "c" in the Hazen and Williams formula fell as low as 93.5. Following a thorough cleansing of the pipe, chloramine was applied systematically in April 1934. From this time until April 1936 the value of "C" in the Hazen and Williams formula had changed from 144 to 138. Ackerman states that the conditions are such that the determination of the value of "C" is accurate within a few per cent.

Laboratory Control. A good laboratory equipped with facilities for some experimental and research work is essential to a modern water purification plant. Pure water for municipal purposes is becoming more and more a highly processed product and this processing cannot be economically or effectively carried out unless under analytical control. For the larger plants there is a marked tendency to place technically trained men in charge, whether engineers or chemists. Both a knowledge of engineering and chemistry is required. For the smaller plants it is not always practicable to have technically trained men. The various water works schools conducted by State Departments of Health are performing excellent service throughout the country in giving non-technically trained men that minimum of schooling that will enable them to operate the smaller purification plants at least reliably if not with the maximum economy. Many analytical determinations have been greatly simplified so that untrained men can learn to use them. The trend in the effort to simplify analytical laboratory work and at the same time encourage analytical control is evidenced in a series of excellent articles by Cox, on laboratory control (46).

Automatic Operation. Some tendency in the direction of automatic operation has developed within the past year. References have

already been made to automatic application of chlorine on the basis of volume of flow and chlorine residual.

Devices are now on the market for a master electric control of chemical feed devices of all sorts in proportion to the flow of water through a Venturi meter.

Zeolite softening equipment has been made practically automatic. This was a development in connection with the production of equipment for household users but has been made applicable to small municipal installations. There is no reason why the automatic principles applied to the washing and regeneration of zeolites could not be applied to the washing of filters.

Barker (47) describes a filter plant at Durham, New Hampshire, which has been made substantially automatic in operation through an arrangement for starting and stopping pumps by water level changes in the sedimentation basin and the clear water reservoir. The plant is visited once per day for washing the filters and general inspection. Otherwise the plant takes care of itself. It may be practicable to look forward to even greater automatic operation of small plants, especially if a number of them are grouped within a relatively small area. Thus a single competent operator could control all of them.

In discussing very small water purification plants such as are used at lighthouses, at life guard stations, on boats and at Indian agencies, Shaw (48) Sanitary Engineer, U. S. Public Health Service, describes more or less automatically operated installations that are effective and reliable. These methods were devised by Shaw to meet requirements on a number of Government properties and reservations where technical control is not practicable.

SUMMARY

In conclusion it may be stated broadly that while no outstanding or radical change has taken place in water purification practice during the past year, yet water works men in general have evidenced intelligent and aggressive approach to the innumerable problems that confront them, and important progress has been made.

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REPORT OF THE JOINT RESEARCH COMMITTEE ON BOILER FEEDWATER STUDIES*

By C. H. Fellows, Chairman

(Detroit-Edison Company, Detroit, Mich.)

The Joint Research Committee is now engaged in three specific studies and has under consideration a fourth project.

The one of these which has received the most widespread attention is that under the direction of Sub-Committee 6, the Chairman of which is Mr. J. H. Walker. The research project of this sub-committee has concerned the problem of caustic embrittlement. As the result of certain disclosures growing out of its studies that have indicated that intercrystalline cracking of boiler metal may be influenced by many more substances than sodium hydroxide, the sub-committee is at present engaged in an effort to clarify the whole picture relating to caustic embrittlement. Whereas the work of Professor Straub and his associates at the University of Illinois has served to point out corrective measures applicable in the majority of cases where this form of metal cracking was encountered, the industry has felt that a clearer understanding of this phenomenon could enable inhibitive treatment to be prescribed for the use of all operators of steam boilers.

The disclosure relating to the effect of silica in promoting embrittlement is now well known in the industry through publications by the Research workers of the sub-committee and by Professor Straub. As a direct outgrowth of that discovery the scope of the project has been extended. A resume of the course of the technical work of this sub-comittee has been submitted through the Chairman by Dr. W. C. Schroeder, in direct charge of the experimental work.

> "The experimental study of the effect of solutions on the cracking of boiler steel has divided into two distinct phases. First, investigation of the chemical and physical factors that produce cracking; and, second, development and investigation of compounds that may prevent cracking.

* Presented at the Buffalo convention, June 10, 1937.

Investigation of the production of cracking. The discovery during 1935 that small amounts of silica played an important part in the cracking of steel at 480°F in sodium hydroxide solutions, opened the road to a conception of the real factors involved in this type of failure. It also led to the tacit assumption that complete exploration of the action of these solutions would serve to correlate practically all the known facts about intercrystalline failure.

As the exploration of the action of these solutions proceeded, many facts were readily understood and brought into line but two definite discrepancies still existed and intensive investigation of these differences has now shown that a wide variety of solutions at temperatures from the boiling point to above 500°F. can produce intercrystalline cracking. Some of these solutions are so effective that visible cracks may be started within one hour, and these cracks will go through a $\frac{5}{16}$ inch section of boiler flange steel in 10 or 12 hours. Moreover, contrary to the belief up to the present time that only very concentrated solutions will cause cracking, it has been found that certain dilute solutions produce intercrystalline failure. Further investigation of the action of the dilute solutions may indicate the necessity of considerable revision in the methods now used to secure protection.

Through a study of the influence of various embrittling solutions on the surface of the steel, it has been possible to offer a theory that serves to correlate most of the information available about this type of failure. The theory has also made it possible to predict certain solutions that will produce failure and it should prove of further value in the study of protective agents.

Investigation of the Prevention of Cracking. Most of the study of the prevention of cracking has been confined to the action of sodium hydroxide-sodium silicate solutions at 80°F, since the effect of other solution combinations has been known for only a short time.

Laboratory results indicate that sodium sulfate prevents failure only under certain limited conditions, and other inorganic salts ordinarily present in the boiler water are of little value, insofar as their action in solution is concerned.

Some organic compounds have been found quite effective in preventing failure and their action is receiving further study.

Additional study of prevention must be made at lower temperatures and with solutions other than sodium hydroxide-sodium silicate. In this investigation the possible influence of the dilute solution must also be determined."

The chairman of Sub-Committee 6 reports further concerning the conduct of the Sub-Committee's activities:

"Receipts, Nov. 1, 1936 to April 30, 1937 (Includes balance on hand Nov. 1, 1936)	$11,862.13
Disbursements Nov. 1, 1936 to April 30, 1937	7,092.40
Balance on hand April 30, 1937	4,769.73
Total available funds for the continuation of this project (Including balance on hand)	14,669.91"

"Committee Meetings. A meeting of the Sub-Committee was held on December 2, 1936 in New York City. No meetings have since been held, but a meeting is scheduled during the session of the A.S.T.M. in New York City the week beginning June 28th. Brief monthly progress reports are made to the committee members and the chairman makes frequent trips to the laboratory. During the past six months Messrs. C. H. Fellows, L. W. Wallace, and R. C. Bardwell, committee members, have also visited the laboratory.

Improved Laboratory Facilities. Within the last few weeks the Non-Metallic Minerals Experiment Station of the U. S. Bureau of Mines has been moved from New Brunswick, New Jersey, to College Park, Maryland, where it occupies ample space and has much improved facilities in a new government building. Undoubtedly the work can be prosecuted much more advantageously under this improved arrangement.

Laboratory Staff. The laboratory work continues under the energetic and competent direction of Dr. W. C. Schroeder, assisted by Mr. A. A. Berk of the Bureau staff and Mr. Robert O'Brien, who is retained by the Committee. These men deserve the credit for the encouraging and valuable findings which have so far been made.

Publications. No reports of the work have been published during the past six months. A report is now being prepared, however, which with the approval of the Sub-Committee will probably be published in one of the metallurgical magazines in the near future. (Progress Report No. 11).

Personnel. The personnel of the Sub-Committee has not been changed during the past six months. It consists of the following:

Mr. Alex D. Bailey	Mr. S. T. Powell
Mr. R. C. Bardwell	Mr. T. E. Purcell
Mr. R. E. Hall	Mr. J. B. Romer
Dr. D. B. Keyes	Mr. R. C. Stratton
Mr. E. B. Powell	Mr. L. W. Wallace"

OTHER INVESTIGATIONS

The work of Sub-Committee 8 (Chairman, Professor A. H. White) has been temporarily stopped pending the adoption of a program and the procurement of funds to enable that program to be carried out. The work of that sub-committee concerns the examination of existing methods, and the development of new methods where necessary, for the determination of ions of significance in boiler-feedwater and boiler water treatment. At the present time Chairman White is preparing a final report on the study of a method for the determination of dissolved oxygen.

A new project that has gotten under way during the past six months is that concerning coagulation and sedimentation, as these processes may be applied in the treatment of feedwater. This work is under the direction of Prof. A. P. Black of the University of Florida, Chairman of Sub-Committee 1. The immediate work which will be undertaken by this sub-committee is the application of these processes to the problem of the removal of silica from feedwater. It is anticipated that a progress report of this work will be available to the sponsor societies by June 1938.

The significance of the presence of silica in the water used in the modern high pressure boiler is becoming recognized. The thin hard scale produced by silica becomes more prominent in high pressure operation and the damaging effects are more serious. Deposits of silica on turbine blading are a serious factor and efforts are continually being made to eliminate this troublesome element from the boiler water cycle.

The fourth project of primary interest to the Joint Research Committee and to the industry concerned with the generation of steam is that of corrosion. The Committee has taken no active steps in inaugurating a study of this subject as yet. It is, however, maintaining an interest in the research project at Purdue University in which the steam-metal reactions at high temperatures and pressures are being studied. This is a subject of major importance to the operators of steam power plants when the temperatures and pressures are continuing to rise. The present maximums are 925°F and 1400 pounds per square inch gage with contemplated constructions considering pressures above 2000 pounds per sq. in. This research project involves about 20 alloy steels and the test conditions cover the temperature range from 800°F to 1200°F while the pressure range extends from 400 to 2300 pounds per square inch. The reaction encountered is that which produces iron oxide at the expense of the oxygen atom in the water molecule. It is apparently a reaction that does not lend itself to the chemical control of the water, since it is brought about by the direct reaction of water or steam on very hot metal.

Although important progress has been made in the past decade in the problems of boiler water chemistry, new conditions of operation continue to emphasize the necessity for constant research in this field. Fundamentally boiler water treatment is the same for high pressure and high temperature operation as for the operation at lower pressures and temperatures. Exactness of control of the chemical reactions involved is the basis for successful treatment of the treatment of water for modern boilers.

On behalf of the officers of the Joint Research Committee on Boiler Feedwater Studies may I take this opportunity to express our appreciation for your moral and financial support. Through the efforts of your secretary, Mr. Jordan, and your associate representative on the Committee, Mr. S. T. Powell, past Chairman, encouragement and many helpful suggestions have greatly influenced the progress of our work.

Respectfully submitted,

C. H. FELLOWS, *Chairman.*

A STUDY OF CONTEMPORARY ZEOLITES*

By Leo F. Collins

(Chemist, The Detroit Edison Company, Detroit, Mich.)

SYNOPSIS

This paper is a compilation of data concerning the chemistry and use of contemporary zeolites. Chemical analyses of raw materials, and of a representative number of new and used zeolites from each of the various classes plus 35 sieve analyses of new and used products, and a résumé of theories concerning the constitution and reactions of base-exchangers constitutes the nucleus of the treatise. It is shown that the chemical composition of natural zeolites is not materially changed by the processing methods used, that the latter are similar in character and that for zeolites of a given class there is little difference in chemical composition. It is also shown that the chemical and physical characteristics of six different zeolites were changed upon use, and it is pointed out that the susceptibility of contemporary products to yield to certain external influences limits their industrial utility, particularly their use in the treatment of waters for steam boilers.

In general the paper establishes a basis for judging the limits within which such materials may be expected to perform with reasonable satisfaction and in the general summary nine precautions are listed for ameliorating the major troubles which are believed to frequently attend the operation of large softeners.

CONTENTS

Introduction 1473

Part I. The Classification, Preparation, and Composition of Contemporary Zeolites

Semi-Natural Zeolites 1476
Glauconites and Their Stabilization 1476
Bentonitic Clays 1478

* Presented before the meeting of the Joint Research Committee on Boiler Feedwater at the Buffalo convention, June 10, 1937. Rewritten from a thesis presented by the author to the Faculty Council, University of Dayton (Ohio) as the final requirement for the professional degree of Chemical Engineer.

Synthetic Zeolites 1479
Precipitated or Gel-Types 1479
Fusion-Type Zeolites 1480
Mongrel Zeolites 1480
Significance of the Chemical Composition of Zeolites 1481
The Sodium Content 1481
The Silica-Alumina Relationship 1482
The Water Content 1482

Part II. The Constitution and Reaction of Zeolites

Suggested Structural Formulas 1483
Suggested Theories of the Base-Exchange Reaction 1484

Part III. Some Characteristics Limiting the Industrial Utility of Contemporary Zeolites

Corrosion in the Water Cycles 1488
Disruption of Gravel Beds 1489
Deterioration of Zeolites 1494
Indices of Mechanical Disintegration 1494
Indices of Dissolution 1495
Some Practical Effects of Attrition and Dissolution 1498
Formation of Silicate Scale 1498
Restabilization of Greensand 1499
Pressure Losses and Bed Expansions 1501
Loss of Softening Capacity 1503
Influence of Physical and Chemical Conditions of the Zeolite 1505
Effect of Influent Temperatures 1505
Effect of Varying Water Velocities 1508
Effect of Salt Used in Regeneration 1508
General Summary 1511

INTRODUCTION

Within a relatively short period of time zeolites have gained a prominent place among the chemicals used for treating waters. The greatest number of zeolite softeners are employed outside the field of industrial treatment, and it has become almost traditional to associate with them only two queries, viz., how thoroughly can they soften a given quantity of water, and how much salt will be required per unit of hardness removed? These queries are of a fundamental nature it is true, but with large industrial softeners there are also additional considerations that are of consequence.

For practically every industrial unit several major benefits can be shown to attend its use, provided it be used intelligently. But, it is also true that the adoption of zeolites in the industrial field has been somewhat stymied by a realization that contemporary zeolites tend

to lose their inherent softening capacity upon continued use, that they disintegrate due to attrition and dissolution, that they frequently cause an inert water to become corrosive and that their supporting gravel sometimes requires rearrangement.

Many of these difficulties could undoubtedly be ameliorated if the chemistry of zeolites were better understood. Unfortunately only a minimum of such information is available, and for some unexplainable reasons, vendors are loathe to reveal technical data pertaining to their products. Some even refuse to clearly describe the different zeolites they offer. Since the treatment of waters for industrial purposes, particularly for steam boilers, constitutes an incidental use for zeolites it does not seem probable that any unusual effort will be made to develop a zeolite to overcome these limitations. Thus for some time to come, it seems inevitable that we must use the materials presently available, and in order to judge the limits within which they may be expected to perform with reasonable satisfaction, it is imperative that their fundamental characteristics be known. This study was made to obtain information along this line. Admittedly, all the necessary information has not been obtained, nor does this publication pretend to offer a final solution to all the problems that arise in the operation of industrial softeners. It is offered in an attempt to stimulate constructive thought upon the subject.

Most of the data herein revealed were collected in connection with studies made upon the use of zeolites for treating boiler water supplies. Since, however, the discussions are restricted primarily to the performance of zeolites and zeolite softeners, to the exclusion of other boiler water considerations, it is felt that this paper may likewise be of value in other industrial applications.

Much propaganda centers around the materials and methods used in the preparation of zeolites. Not infrequently does a vendor contend that, because of the superb quality of the raw material used, and/or because of the unique method of processing employed, his product is vastly superior to others in its class. Rarely, however, are data advanced to support this contention.

To determine to what extent such contentions may be valid, an effort was made to obtain information along this line by assembling analytical data on raw materials, the finished products and a general idea of the various processing methods used. This information is set forth in Part I.

A detailed study of the available literature was made in obtaining

the aforementioned information. This automatically led to a review of the various theories that have been advanced to explain the structure of zeolites and the manner in which they react. A résumé of these theories has been prepared and constitutes the material of Part II.

After compiling Parts I and II the fundamentals therein revealed were applied in the correlation of data from operating softeners. These data, and discussions of their significance, are included in the third part. They show, quite conclusively, the limiting characteristics exhibited by some of the more common base-exchangers: and they pointed out, indirectly, the absolute need for reliable laboratory methods for testing zeolites as a prerequisite for further development. Using these data as a basis a group of test methods, similar in part to those proposed elsewhere (1) (2), have been prepared, but because of the fact that only a few persons are interested in such considerations, they are not included herein.

PART I. THE CLASSIFICATION, PREPARATION, AND COMPOSITION OF CONTEMPORARY ZEOLITES

The word "zeolite" is of Greek origin and was coined to identify only those substances which swell and boil when strongly heated. Some true zeolites are capable of base-exchange; others are not; some substances capable of base-exchange are not true zeolites at all. The term as commonly used, however, does not retain this strict mineralogical significance but rather is used to identify those materials capable of exchanging both anion and cations. This conventionality will be observed throughout the remainder of this paper, and it is recognized now that "zeolites" are used for purposes other than to soften water. Nevertheless, it is their use for the latter purpose that is the sole concern of this treatise.

Contemporary zeolites may be classified as follows:

A. *Semi-Natural Zeolites.*

1. Treated Glauconites, i.e., greensands.
2. Treated Bentonitic clays.

B. *Synthetic Zeolites.*

3. Precipitated and Gel Types.
4. Fusion Types.

C. *Mongrel Zeolites.*

This classification, while not as pretentious as some that have been made (3) (4), is nevertheless adequate for the purpose at hand. It

indicates that no natural zeolites are used. This is true. All the so-called natural zeolites are processed, and the synthetics are, as the term implies, artificially prepared.

Semi-natural Zeolites

The two types of zeolites included under this caption differ principally as regards their physical texture. The latter is largely a function of the raw materials from which they are derived.

Glauconites and Their Stabilization. It is well known that products in this class are obtained, for the most part, by the treatment

TABLE I

Analyses of Raw Glauconites from New Jersey Deposits—Percent by Weight*

	1	2	3	4	5	6
Silica—SiO_2	47.6	48.8	50.0	48.2	52.5	50.4
Iron Oxides and Alumina	30.2	29.9	27.9	27.4	28.5	29.1
Lime—CaO	2.2	1.3	2.1	4.1	0.3	0.4
Magnesia—MgO	2.3	2.6	3.1	2.6	3.0	3.5
Soda and K_2O	8.9	8.6	7.5	7.3	7.7	8.2
Water @ 100 C	4.5	3.5	5.1	0.6	0.0	8.8
Water Above 100 C	4.4	5.2	4.4	7.8	8.1	
	100.1	99.9	100.1	100.0	100.1	100.4

* Recalculated from Analyses by Cook—see (6).

1. "Lower marl bed," Marlboro, Monmouth County.
2. "Middle marl bed," Blackwood, Camden County.
3. "Upper marl bed," Squankum, Monmouth Country.
4. "Lower marl bed," Cream Ridge, Monmouth County.
5. "Middle marl bed," White Horse, Camden, County.
6. Sewell, Gloucester County—see (7).

of greensands from the New Jersey deposits. Ashley (5) has described raw greensand as follows:

> "Under the magnifying glass, the best greensand appears to be composed entirely of grains of glauconite, less than one per cent being grains of quartz sand. More commonly it includes a large proportion of quartz sand, amounting to one-half or more of the whole. Sand that is composed mainly of grains of glauconite is dark green to light green and becomes darker or almost black when wet. . . . The grains of glauconite are fairly soft and can readily be broken by the finger nail."

Cook (6) in studying the greensand deposits of New Jersey carefully selected grains of glauconite from a number of deposits. His analyses show that these have a composition typified by the data in table I.

Such glauconites are used in the production of greensand zeolites. Untreated greensands possess base-exchange properties but are not used, in the raw state, because the individual grains readily disintegrate. Hungerford (7) has stated that when an attempt is made to use raw glauconite as much as one-third of the material may be broken up and carried away by the water during a single regeneration. He believes too that disintegration is most rapid in soft water and experience has shown that this is true even after "stabilization."

By stabilization of a greensand is meant subjecting it to certain chemical and (or) mechanical treatments. Shreve (8), in his commendable "Greensand Bibliography to 1930," lists 20 different methods of treatment. It appears that those methods involving principally a heat treatment have been abandoned and a careful scrutiny of the others show that they have many points in common.

The initial step in practically all proposes to remove, by washings mud, fine grains of glauconite, quartz sand, etc., from the original material. In some cases the material so removed amounts to as much as 50 percent of the original. The sand finally selected invariably falls within the range 16 to 80 mesh (1.19 to 0.19 mm.) although some manufacturers specify a slightly narrower range.

After being graded, the sand is "scoured"—usually with a caustic solution. The use of caustic, so it is claimed, is of dual value in that it disintegrates and dissolves the less stable grains, and it increases the content of exchangeable sodium in the residual sand. Subsequent treatments, with sodium silicate, and finally with a weak acid solution (usually an amphoteric salt such as aluminum sulphate) are supposed to encompass each grain in a hard silica envelope.

After stabilization zeolites in this class appear on the market with trade names such as Greensand, or Treated Greensand, Basex, Borromite, Inversand, Hi-inversand, Kenzolite, Zeo-Dur, Super-Zeo-Dur, Verdite, Zeopholite, and possibly others. A chemical analysis of six zeolites in this class gave the results shown in table II.

It can be seen from these analyses that insofar as the chemical composition of the more common greensands is concerned there is little difference between them. This probably is to be expected, in view of the fact that many of the raw materials are taken from the

same *general* geographic locality, and because the processing methods used are similar in character.

Bentonitic Clays. Tiger (1) has reported that base-exchange materials in this class are prepared principally from clays found in the Dakotas. These clays have a chemical composition typified by analysis No. 1, shown in table III.

TABLE II

Analyses of Stabilized Greensand Zeolites—Percent by Weight

	CODE DESIGNATION					
	A	B	C	D	E	F
Silica—SiO_2	48.89	48.80	48.49	48.68	46.60	52.06
Oxides—Fe_2O_3 and Al_2O_3	32.28	31.00	32.12	35.28	33.83	30.00
Lime—CaO	1.60	1.40	0.86	1.56	1.63	1.68
Magnesia—MgO	4.19	4.11	3.68	0.20	4.11	3.81
Soda and K as—Na_2O*	8.76	7.81	9.17	7.07	3.60	7.70
Ignition Loss	4.69	6.88	5.37	7.21		5.25

* Calculated Value.

TABLE III

Analysis of an Unprocessed and Processed Bentonitic Clay—Percent by Weight

	NO. I UNPROCESSED	NO. II PROCESSED—CODE L
Silica—SiO_2	60.60	58.20
Oxides—Fe_2O_3 and Al_2O_3	25.88	26.78
Lime—CaO	2.08	1.15
Magnesia—MgO	4.59	2.70
Soda and K as Na_2O_3	1.08	3.96
Ignition Loss	5.82	7.41

According to Shreve, about five methods have been suggested for treating bentonitic clays in order to render them fit for softening water. In general these consist in leaching the clay in caustic solutions, sizing, baking at high temperatures, rehydrating, usually in caustic soda solutions, and finally treating with sodium chloride solutions.

Since these clays, in the plastic state, are frequently extruded through dies, zeolites in this class usually exhibit a more uniform

grain size than do other zeolites. Because of their physical uniformity, Terry (9) has opined that softeners utilizing processed clays can be operated at higher flow rates than are possible with either glauconites or synthetic zeolites. From a mechanical standpoint high flow rates are possible, but, from a chemical standpoint this is not entirely true.

Synthetic Zeolites

The first zeolites *made* by Gans (10) were of the synthetic precipitated type. Behrman (11) and others (12) contend, however, that the zeolite *used* by Gans (13), in his initial attempt to soften water on a practical scale, was of the fusion type.

Baker (14) has summarized the methods for preparing either type very concisely by stating:

> "The patents for the preparation of (synthetic) base-exchange zeolites provide for two general methods of manufacture, (a) fusion of aluminous or ferrous, etc., materials or silicates with alkali silicates or alkali hydroxides or carbonates; and (b) precipitation by treating an alkali aluminate solution with hydrated silicic acid and drying and washing the mass."

Precipitated or Gel-Types. In producing zeolites in this class (15), solutions of sodium silicate and aluminum sulphate (16), or sodium silicate and sodium aluminate (17), or sodium silicate, sodium aluminate and alum (18), or simply sodium silicate and alum are mixed together. If the temperature and concentrations are optimum the whole mass will solidify into a stiff gel. The gel is then dried at moderate temperatures (below 120 F) or it may be washed and filter-pressed and then dried. In either case the dried gel is finally broken into sizes suitable for softening purposes. A more novel method of dehydrating the gel consists in freezing it (19). During the freezing process, the zeolite grains form more or less cubical under the ice. When the ice is thawed the crystals deposit and the mother liquor is drained away. The crystals are then washed, dried, and screened.

Crystallite, Doucil, Decalso, and Burgess are most common in this country. A chemical analysis of four zeolites in this class is shown in table IV.

It should be understood that a zeolite appearing on the market under a given trade name will not necessarily conform to the analysis

shown for it in table IV. On occasions, the silica and alumina contents are intentionally varied in manufacture.

Fusion-Type Zeolites. Zeolites in this class are prepared by heating to the melting point mixtures of sodium carbonate, kaolin, and feldspar (20), or by adding to the mixture just described potassium carbonate (21) and other similar combinations (22) (23) (24) (25),

TABLE IV

Analyses of Gel-type Synthetic Zeolites—Percent by Weight

	CODE DESIGNATION				
	G	H	I (1)	I (2)	J
Silica—SiO_2	41	63.32	57.08	55.96	57.44
Alumina—Al_2O_3	23	11.12	19.96	20.44	17.60
Lime—CaO		0.20	0.72	0.68	0.86
Magnesia—MgO		0.64	0.18	0.17	0.58
Soda—Na_2O*	17	9.90	3.51	4.95	6.65
Ignition Loss	18	14.82	18.55	17.80	16.87

* Calculated values.

(1) Grain size from 2.38 mm. to 0.59 mm.

(2) Grain size from 0.59 mm. to 0.297 mm.

TABLE V

Analysis of a Fusion-Type Synthetic Zeolite—Percent by Weight

	CODE—K
Silica—SiO_2	44.38
Oxides—Fe_2O_3 and Al_2O_3	26.49
Lime—CaO	1.26
Magnesia—MgO	1.08
Soda—Na_2O	14.19
Ignition Loss	13.62

followed by cooling, crushing, and sizing. So far as can be learned no fusion type zeolite is now made in commercial quantities. One of the older synthetic zeolites, was so prepared (20). Its analysis is shown in table V.

Mongrel Zeolites

In the foregoing paragraphs, the composition of the more common zeolites was considered. They have been shown to consist princi-

pally of silica, alumina (or the equivalent Fe_2O_3), alkali, and alkaline earth metals.

It has been claimed, too, that base-exchangers have been prepared by substituting borates for silica, and lead, zinc, tin, titanium, zirconium, and chromium oxides for alumina (26) (27) (28). Attempts also have been made to prepare zeolites from trass, volcanic rock, boiler slags, and lignite. These "unusual" zeolites, however, have never received wide distribution.

Just recently some so-called "synthetic resins" have been developed which because of their exchange properties are classed as zeolites. Some of these resins exchange anions, and some cations. Some are condensation products, prepared from formaldehyde with polyhydric phenols and amines. Experiments with one of these, which is regenerated with sulphuric acid, are now being conducted but the results do not warrant discussion at this time.

Significance of the Chemical Composition of Zeolites

Judging from the foregoing data it appears that the composition of zeolites of a given class is quite uniform regardless of the processing methods employed. Exactly what significance can be attached to the chemical composition of a zeolite is not known. In the United States Hulbert (29), Frankforter and Jensen (30) are the only ones to publish information concerning investigations conducted in this field. Their work is not conclusive. It will be of value, however, to review briefly what is believed to be the significance of the three common constituents of base-exchangers.

The Sodium Content. Normally sodium is the exchangeable base ion in a zeolite used for water treatment. In operation not all of that present is exchanged for calcium and magnesium although the amount present is an index of the exchange capacity of the zeolite. Gunther-Schulze (31) was of the opinion that 96.5 percent of the sodium in the zeolites with which he worked was replaceable by silver. He based his views upon conductivity measurements. At a later date Frankforter and Jensen (30) investigated the amount of sodium which could be replaced by calcium, and barium and vice versa. They concluded that sodium compounds other than sodium zeolite were present and thus accounted, at least in part, for the fact that complete exchange was unattainable. They found, too, that sodium was always replaced by a chemically equivalent amount of alkaline earth metal or vice versa. Austerweil's (32) hypothesis, which will be reviewed later, shows that all the sodium cannot be

replaced unless an infinite amount of solution is used, even though it be present as an integral part of the zeolite.

The Silica-Alumina Relationship. Mattson (33) has opined that the amount of base which will be exchanged by a given zeolite at equilibrium is dependent principally upon the relation between the SiO_2 and Al_2O_3 present. This is in conformity with Austerweil's view, that the ratio Al/Si determines the amount of replaceable base present. In artificial zeolites this ratio may vary from 1:4 to 1:15, and in general it is found that the higher the silica content the lower is the exchange capacity but the more resistant is the material to disintegration.

The Water Content. All zeolites contain water which is loosely held and in some synthetics this may amount to as much as 50 percent of their weight. Most of this can be removed by heating. On the other hand, all zeolites contain some water which cannot be removed by simple methods. Some investigators opine that five molecules of water are present; two as water of constitution and three as water of crystallization. This is not a definitely established fact. Other authorities (34) (35) have contended that there is no distinction between the molecules of water and have conducted experiments indicating the presence of as many as fourteen hydrates. Again some (36) workers indicate that the water is held in solid solution while others (37) contend that zeolites are gels and retain their water in a closely knitted framework of alumina and silica. Whether or not any of these views are correct no one knows, but in support of the latter contention, it is significant that the vapor pressure water content diagram of many synthetic zeolites resembles that for true gels, since both exhibit hysteresis. Because of the latter fact, some artificial zeolites are rehydrated rather than dehydrated in "fixing" their water content. Rothmund (38) has reported that chabazite can be rehydrated completely if it has not been heated above 600°C. but that this is impossible if dehydration has been effected above 800°C. Some of the highly hydrated zeolites, as for instance Doucil, if thoroughly dried and then dropped suddenly into water disintegrate spontaneously.

PART II. THE CONSTITUTION AND REACTION OF ZEOLITES

In view of the large amount of work that has been done in developing commercial zeolites, one would expect that their constitu-

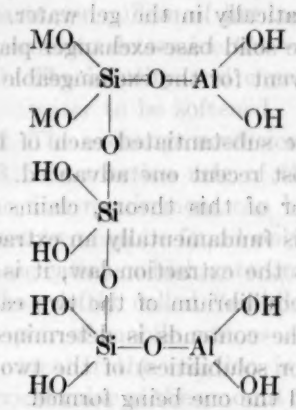
tion would be quite thoroughly understood. This, however, does not seem to be the case. To obtain even an inkling of their probable constitution, Gans' original postulate must still be accepted.

This pioneer investigator prepared complex alumino-silicates in two ways:

1. By dissolving hydrated alumina in sodium hydroxide and then adding silicic acid while evaporating to dryness at about 212 F.
2. By adding hydrated alumina to an alkali silicate under the conditions mentioned above.

The end product in both cases had substantially the same chemical composition but only the one prepared by the first method exhibited base-exchange properties. This difference in behavior Gans attributed to a difference in structural arrangement of the molecule. Thus, he suggested the hypothesis that when the alkali or alkaline earth metal is bonded to aluminum through oxygen it is replaceable but that when bonded through oxygen to silica it is not replaceable.

Suggested Structural Formulas. Martin (39) demonstrates the two conditions suggested by Gans' postulate by means of the following structural formulas, in which M represents the replaceable base metal.



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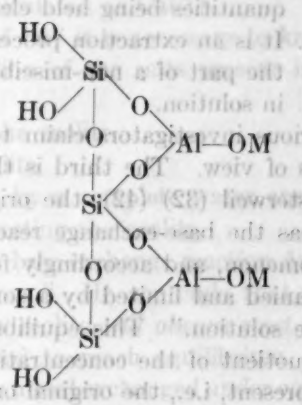

(Active)

The formula to the right, he points out, meets the following theoretical requirements:

1. A bonding of the replaceable base to aluminum through oxygen as required by Gans' hypothesis.

2. A ratio of unity between the Al_2O_3 and replaceable base metal also as suggested by Gans.
3. The normal valence of all constituents, is satisfied.

With our present knowledge it must be admitted that such a formula is only a demonstration. Therefore, it is incapable of inferring many of the properties of the materials. Some well informed do not subscribe to Gans' theory. Behrman (11), for instance claims that the preparation of synthetic zeolites from compounds in which aluminum appears as a positive radical is a "direct refutation of the theory of Gans and his followers." Stremame (40) and Weigner (41) regard alumino-silicates as mixed gels and not true chemical compounds.

Suggested Theories of the Base-Exchange Reaction. The promulgation of theories, to explain the mechanism of the base-exchange reaction, has provided more speculation than any other consideration connected with the chemistry of zeolites. Divested of their trappings, however, the various theories may be summarized by one of the following statements:

1. It is a heterogeneous chemical reaction governed by the law of mass-action.
2. It is an absorption phenomenon, the cations in equivalent quantities being held electrostatically in the gel water.
3. It is an extraction process, the solid base-exchanger playing the part of a non-miscible solvent for the exchangeable ions in solution.

Various investigators claim to have substantiated each of these points of view. The third is the most recent one advanced.

Austerweil (32) (42), the originator of this theory, claims that whereas the base-exchange reaction is fundamentally an extraction phenomenon, and accordingly follows the extraction law, it is "accompanied and limited by a sort of equilibrium of the two cations in the solution." This equilibrium he contends is determined by the quotient of the concentrations (or solubilities) of the two zeolites present, i.e., the original one and the one being formed.

Upon this premise, he applies the extraction law to show that the quantity of any zeolite required to soften a water *completely* may be deduced by means of the equation

$$(1 - a)^n = 0 \qquad \text{(Equation I)}$$

where unity = the initial hardness of the water
a = the "exchange coefficient" of the zeolite
n = number of extractions required, when an amount of zeolite is used (in each extraction) which contains a quantity of replaceable base equivalent to that in the water being softened.

Equation I clearly shows that to obtain absolute "zero hardness" an infinite amount of zeolite would be required. Softening to such a degree is obviously unattainable and fortunately unnecessary. Even for boiler purposes, which is perhaps the most exacting task to which a zeolite may be put, it seems a reasonable conclusion that from four to six parts per million of residual hardness are tolerable and within the limits of good operating practice. If this be conceded, then his more practical equation applies, viz:

$$n = \log \frac{(1 - E)}{(1 - a)} \qquad \text{(Equation II)}$$

where E = fraction of hardness removed, and where "a" has the same value as in equation I. The limit previously set forth, relative to boiler water, decrees that (1-E) should never be more than six parts per million of hardness, calculated as $CaCO_3$.

In order to determine the value of "n" it is necessary to know:

1. The identity and concentration of the salts present in the water to be softened.
2. The exchange coefficient of the zeolite.
3. The reaction rate of the zeolite.

The first requirement can be met by a complete water analysis; the last two can be found only by testing the zeolite.

Those cations which enter into the base-exchange reaction Austerweil has deftly called "mobile cations." He contends that for a given pair of mobile cations a given zeolite *will always react to the same extent* if the reaction is allowed to reach equilibrium. The numerical value of the amount of base metal exchanged under equilibrium conditions he calls the "exchange-coefficient." If Austerweil's contention is correct, namely, that the same zeolite will *always* react with the same water to the same numerical extent, then it appears that the determination of "exchange coefficient" would be a more suitable index for judging the quality of a zeolite than the

conventional index of exchange capacity, because it can be measured under conditions which can be more definitely controlled.

Very little work has been done in determining the velocity of the base-exchange reactions. From the information available (32) (9) (43), it appears that for most commercial zeolites equilibrium is reached in less than thirty minutes. This, of course, is of little practical concern. In actual operation, it is usually impractical to afford contact time between zeolite and water of more than five minutes.

From a practical point of view, there are five items of importance to be remembered in connection with the base-exchange reaction:

1. The exchange of one base for another is never complete but proceeds until equilibrium is established, the latter being dependent upon the concentration of bases in aqueous solution.
2. This equilibrium is a true one since it can be established from either side.
3. Chemically equivalent amounts of bases are exchanged.
4. Presumably exchange takes place on the surface and in porous zeolites is governed by the rate of diffusion of the base metal outward to the surface.
5. The velocity of the reaction is high for non-porous zeolite but is much slower for those artificially prepared and for the processed clays.

PART III. SOME CHARACTERISTICS LIMITING THE INDUSTRIAL UTILITY OF CONTEMPORARY ZEOLITES

The data presented in this section were collected from thirteen different softeners using six different zeolites. Seven of the units were used in the treatment of water for steam boilers, four for general softening requirements (hotel use), and two were semi-plant-scale laboratory units. These facts, together with other important statistics are given in table VI.

With present day zeolites one should not expect perfect performance from any system. The degree of perfection obtained depends in large measure, upon the intelligent selection of the zeolite, upon the proper design of the zeolite tank, and allied equipment. For boiler water treatment it is often necessary to follow zeolite with a supplementary treatment in order to maintain conditions in conformity with accepted criteria. The improper design of supplementary feeding equipment as well as the non-observance of

design precautions within the softener itself may conspire to deteriorate the zeolite, whereas by proper design these possibilities may be eliminated.

It should not be inferred from this paper that contemporary zeolites are totally inadequate in the industrial field. The author has shown elsewhere (44) that in the treatment of boiler water supplies, at least five benefits of major proportion have been found to attend their use in two of the systems herein discussed. These are:

1. Desirable chemical conditions were more uniformly maintained than would be possible with internal methods of treatment.
2. Burned tubes, resulting from scale formations, were eliminated.

TABLE VI

Statistics Relating to the Systems Studied

SYSTEM DESIGNATION	NO. OF UNITS INVOLVED	FT^2 ZEOLITE PER UNIT (INITIAL)	ZEOLITES USED (CODE—DESIG.)	PURPOSE OF SYSTEM
A	3	800–900	Greensand—A	Boiler H_2O-Treatment
B	3	275–300	Greensand—B	ditto
C	1	40	Gel-Synthetic—H	ditto
D	1	14–16	Gel-Synthetic—J	Experimental
E	1	1.5–2.0	Ben.-Clay—L	Experimental
F	2	50	Gel-Synthetic—I	General softening
G	2	120–130	Gel-Synthetic—I	ditto

3. As a direct result of benefits Nos. 1 and 2, an increase in steam generating capacities was effected.
4. The number of man-hours required for cleaning boilers and adjacent equipment was reduced.
5. The costs for operating the treating systems were low.

But, despite the fact that more than ordinary caution was used in the operation of these softeners, difficulties of major importance were also encountered. Since most of these were common to softeners in each system, and since the remedial measures which were volunteered by vendors were so numerous, the writer suspects that such troubles are quite universal. The difficulties encountered were:

1. Active corrosion in all lines carrying zeolite softened, non-deaerated, water.
2. Disruption of the beds of retaining gravel.

3. Disintegration and dissolution of the zeolites, and, therefore, loss of zeolite.
4. A steady loss of inherent exchange capacity in the zeolites themselves.

Corrosion in the Water Cycles

Systems A and B were the only ones in which corrosion measurements were actually made. In all the systems studied, casual observations indicate that active corrosion occurs on all ferrous surfaces handling soft, undeaerated water. In System A, mechanical deaeration of the water does not completely arrest the action but the addition of a small amount of caustic to the deaerated water has been found effective. Most of these facts are demonstrated by the data shown in table VII.

TABLE VII

Corrosion Rates Measured at Various Locations in the Water Cycles of Plants A and B

CORROSION RATE*	LOCATION WHERE MEASUREMENT WAS MADE
	In Plant A
1.9	Influent line to zeolite softeners.
18.2	Effluent line of zeolite softeners.
29.2	Tank receiving partly acidulated zeolite softened water and condensate.
2.5	Main boiler feedline after deaeration and addition of caustic.
	In Plant B
1.9	Influent line to zeolite softener.
31.2	Tank receiving partly acidulated zeolite softened water and condensate.
60.0	Main boiler feedline without deaeration.
0.8	Main boiler feedline with deaeration.

* Values are inches penetration per year × 1000.
A corrosion rate greater than 20 is considered serious.
Data obtained with NDHA Corrosion Tester. See Reference (45).

In the cold water lines of Plant A experiments with protective coatings have been conducted. Thus far only cement lining has been found effective. Inside the softeners the application of a bitumastic paint has measurably decreased the evidences of corrosive action.

Disruption of Gravel

In zeolite softeners of conventional design, the zeolite is invariably supported by a retaining layer of graded gravel. The usual arrangement is as shown by the sketch in figure 1.

In both upflow and downflow softeners, it occasionally happens that the gravel, especially the upper or fine layers, becomes shifted. This allows the finer zeolite to come into contact with the coarsest gravel. As a result, zeolite is washed from the unit during "downflow" operation. In softeners which operate on the upflow principle, this may escape notice for a considerable length of time because of the fact that the units are washed downward only during regeneration, a process requiring a comparatively short space of time. This was an experience in System A.

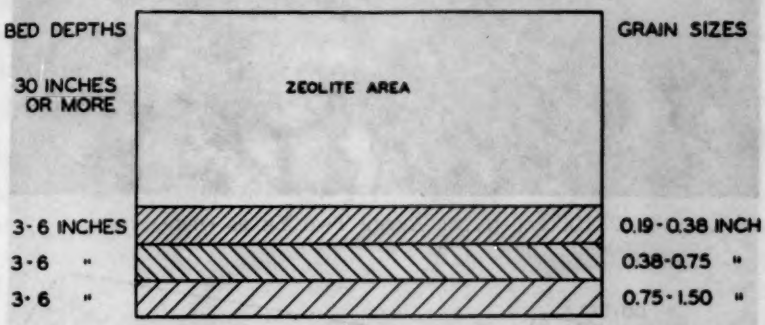

FIG 1 TYPICAL ARRANGEMENT OF RETAINING GRAVEL BEDS IN ZEOLITE SOFTENERS

In the latter system, the units were initially equipped with gravel. They were operated manually during the first two years at a rate of 4.5 gallons per square foot of area per minute and no troubles were noted with the gravel. Prior to the third season of operation, however, a mechanism was installed for automatically putting the units into operation. This equipment was, at the time, incapable of controlling the flow rate at the very beginning of the run. Within the same season, it was found that the total softening capacity of each unit was not as consistent as it had been, that during the downwashing operation some zeolite was escaping. In one unit the zeolite was carefully removed and it was seen that the fine gravel had shifted as shown by the photograph in figure 2.

It was the opinion of one vendor that this could be satisfactorily

prevented by the installation of a cross-sectional retaining system. Following his recommendation, a system, arranged as shown by the sketch in figure 3, was made of fifteen gage Toncan steel. Each

FIG. 2. GRAVEL LAYER AFTER TWO YEARS OPERATION

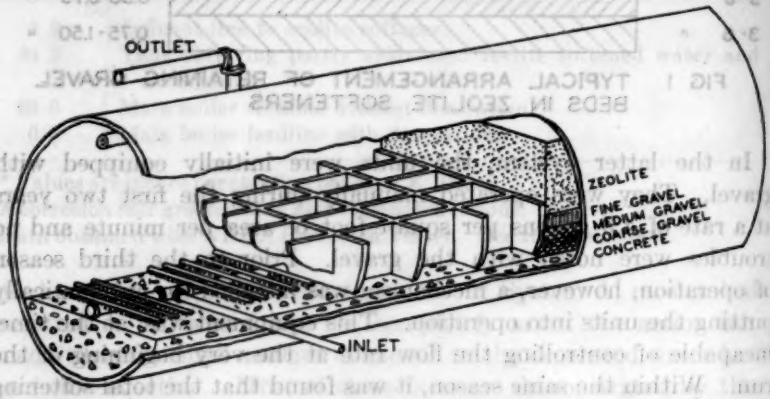

FIG 3 SKETCH OF A CROSS-SECTIONAL GRAVEL RETAINING SYSTEM

compartment was two feet square. Two sections were provided, each one foot high. The top section was superimposed upon the lower one and was "spot-welded" thereto. The lower edge of the

bottom section was then spot-welded to the softener shell and to the water distributing pipes in the bottom of the unit. Since the gravel bed was only eighteen inches (six inches of each layer of gravel) thick, the retaining system extended into the zeolite bed to a distance of about six inches.

Less than six months of operation proved that the system just described was ineffective. The photograph in figure 4 shows the condition that was found to exist in one unit after the zeolite had been carefully removed. When this was discovered, it was evident that the fundamental cause for shifting of the gravel was not known,

FIG. 4. DEFECTIVE BAFFLE SYSTEM IN GRAVEL LAYER

but it was difficult to understand why the retaining system was so completely disarrayed. An explanation for both was eventually found by investigation conducted in an experimental pyrex-glass softener.

With the glass unit, it was clearly shown that when a zeolite unit is completely drained, large quantities of air are sucked into the zeolite and gravel beds. When the unit is subsequently refilled through the bottom at a rate greater than about two gallons per square foot of bed area per minute, the entrapped air will not diffuse through the wet zeolite at a rate sufficient to compensate for the volume of water entering. Thus, the entire zeolite bed is pushed

upward ahead of a column of air. Eventually, the zeolite bed will give way at a chance location and as a result the entrapped air rushes to the "hole" and escapes. The flow of air to the void is horizontal and is followed by a similar flow of water. The high rate of flow, even in the experimental unit, was seen to be sufficient to carry along the finest gravel into a mount directly below the point from which the air had escaped. Further, it was seen that when a mound had been started it would continue to grow upon successive use of the softener.

Subsequent to these experiments a softener containing 800–900 cubic feet of greensand was completely drained. The manhole plate was removed for observation purposes and the unit was then filled at a flow rate of about 4.5 gallons per square foot of bed area per minute. It was found that the entire layer (250 square feet in area) was pushed upward approximately eighteen inches before the entrapped air escaped; that the latter occurred at a chance location and that the geyser of water which followed the air deposited considerable fine gravel on top of the zeolite.

In another series of tests, it was demonstrated that, when the gravel retaining system extended an appreciable distance into the greensand, it would be pulled entirely out of the gravel by the zeolite as the latter was forced upward with the entrapped air; that if the partition plates were not extended above the level of the gravel, this would not occur. The retaining system in a large greensand softener was redesigned upon the basis of the last described observation, and while it remained intact over a period of about six years, it did not successfully prevent shifting of the gravel. An explanation of this paradox is available. It is definitely known that upon one or more occasions the unit in question was filled (from the bottom) at a rate sufficiently high to start shifting the gravel above the partition plates and it is known positively that the mound continued to grow with successive days of service.

From these experiences it would appear, that for industrial purposes, the presence of a gravel layer imposes a limitation. In the cases of systems A and B they have been eliminated. In place of gravel, inlet nozzles so designed as to permit both up and down flow are used. Procuring this nozzle was a development proposition. The type finally selected after experimentation with five different kinds is shown in figure 5 together with curves showing the pressure drop and velocities through the throat and slots for varying inlet

pressures. Experience obtained in developing this nozzle indicated that for such a strainer to be satisfactory it must meet the following requirements:

1. It, in conjunction with others and a lateral piping system, must distribute water evenly to all parts of the zeolite.
2. It must retain the finest zeolite when the softener is washed downward, and not send out jets of water at such a velocity as to cause attrition of the zeolite immediately adjacent to the nozzle when washed upward.

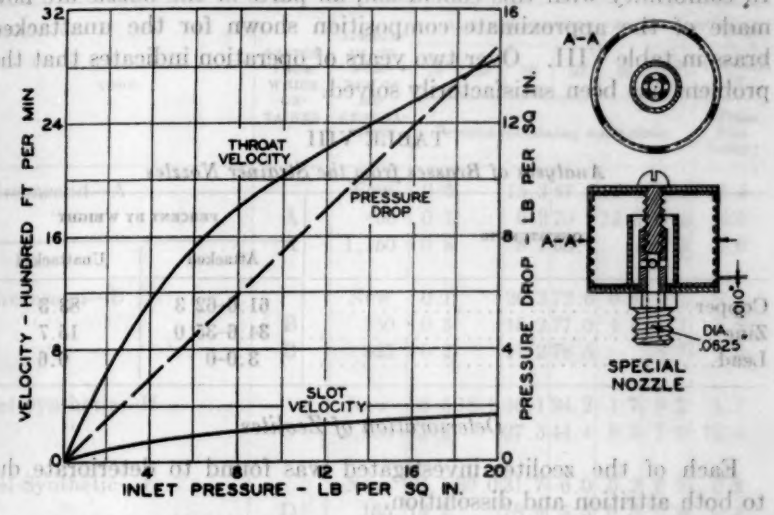

FIG 5 DESIGN OF WATER NOZZLE USED TOGETHER WITH CURVES SHOWING ITS OPERATING CHARACTERISTICS

3. It must not corrode even though it is immersed in a very active corrosion producing medium.

Difficulties under the first two points were avoided in the initial design of the nozzle, but this was not the case under item three. In one unit very active corrosion of iron distribution pipes in contact with the brass nozzles was experienced. This electrolytic action was anticipated and has been overcome by using hard rubber bushings. It must be admitted, however, that from an overall standpoint hard rubber bushings are not satisfactory. They become more brittle upon use, and, as a result, break off and dislodge the nozzles.

The most disastrous experience encountered was the dezincification of certain parts of the nozzle itself. This peculiar phenomenon was noted to occur principally upon the "shank" and "head-plate." The "barrel" seemed to be unattacked. Analyses made of the brasses in these locations gave the results shown in Table VIII.

Research work by Bassett and David (46) indicates that brasses of the approximate composition 85 percent copper, 15 percent zinc are the most resistant to corrosion in sea water. This, it is thought, explains the lack of appreciable corrosion on the barrel of the nozzle. In conformity with this conclusion, all parts of the nozzle are now made of the approximate composition shown for the unattacked brass in table VIII. Over two years of operation indicates that the problem has been satisfactorily solved.

TABLE VIII

Analyses of Brasses from the Strainer Nozzles

CONSTITUENTS	PERCENT BY WEIGHT	
	Attacked	Unattacked
Copper	61.6–62.3	83.3
Zinc	34.6–35.0	15.7
Lead	3.0–0	0.6

Deterioration of Zeolites

Each of the zeolites investigated was found to deteriorate due to both attrition and dissolution.

Indices of Mechanical Disintegration. As an index of mechanical disintegration, a screen analysis of each of the used zeolites is compared in table IX with a similar analysis of the unused product. From these data, it can be seen that in every case the zeolites became finer upon use. What the limit in this regard may be is not known. It is the writer's opinion that when more than 5 percent of a representative sample passes through a 70 mesh U. S. Bureau of Standards sieve, the zeolite bed should be graded to remove the fines.

It is a matter of opinion whether or not the rate of attrition is greatest in units which operate downflow or upflow. It is reasonable to suppose, however, that maximum attrition does occur in upflow operation, because of the increased agitation given the zeolite bed. Further, it is a certainty that upflow operation provides optimum

conditions for the loss of fine zeolite. It is well-known that the finer the grains the more readily will they float out with the water and upflow operation keeps most of the fine zeolite at or near the top of the bed, as is conclusively proven by the data in table X.

Indices of Dissolution. Proof that a zeolite will dissolve in water may be obtained by analyzing the water before and after softening and comparing the values for $SiO_2 + Al_2O_3$ (in the case of the so-

TABLE IX

Comparative Screen Analyses of Zeolite Upon Consecutive Regenerations

CODE	SYSTEM FROM WHICH OBTAINED	APPROXIMATE NUMBER OF REGENERATIONS	U. S. BUREAU STDS.—SIEVE NUMBERS						
			16	20	30	50	60	70	Through 70
			Percent remaining upon sieve						[Grain Size Index]
Greensand—A		New	0.5		15.3	67.8	10.4	4.0	2.5
"	A	450	0.1		6.2	70.1	12.3	6.6	3.9
"	A	1,150	0.8		8.7	65.4		20.3	5.0
Greensand—B		New	0.1		26.3	72.6	0.7	0.1	0.1
"	B	350	0.3		15.2	77.0	4.5	1.7	1.2
"	B	825	0.2		11.2	78.5		8.7	1.3
Gel-Synthetic—H		New	8.6	18.2	46.1	24.2	1.7	0.2	1.1
"	C	2,450	3.2		27.3	44.4	9.9	7.0	15.4
Gel-Synthetic—J		New	25.5	36.0	31.7	6.0	0.2	0.1	0.1
"	D	165	14.2		78.9	5.5	0.5	0.2	0.4
Bentonitic Clay—L		200	2.5	31.9	54.3	10.2	0.2	0.3	0.3
"	E	250	3.8	32.0	50.3	12.0	0.8	0.2	0.3
Gel-Synthetic—I		New	2.1	14.8	44.6	32.2	3.1	0.1	1.9
"	F	400	0.5	0.7	19.9	62.5	9.4	3.5	3.6
"	G	500	0.2	0.2	14.5	75.7	6.7	1.6	0.4

called natural zeolites the $SiO_2 + Al_2O_3 + Fe_2O_3$) so obtained. These oxides are the principal constituents of any zeolite and, therefore, if present in the effluent in larger amounts than in the influent it is a certainty that dissolution has taken place.

For any zeolite, the amount dissolved by a water of low silica content depends upon (a) the length of time the zeolite is in contact with the softened water, (b) the state of regeneration, i.e., whether

TABLE X

Screen Analyses of Zeolites From Various Bed Strata

MESH DESIGNATION*	NUMBER OF TIMES ZEOLITE REGENERATED	Percent of Bed Depth									
		(Top) 0 to 1.0	0 to 20	0 to 25	20 to 40	25 to 50	40 to 60	50 to 75	60 to 80	75 to 100	(Bottom) 80 to 100
From System A											
16	1,150	0.0	0.0		0.0		0.0		0.0		4.1
30		2.9	5.5		8.6		8.5		9.8		10.9
50		28.6	61.3		67.7		66.9		67.2		64.0
70		20.1	24.1		20.3		20.7		19.5		17.0
Through 70 (Grain Size Index)		47.9	8.9		4.1		3.8		4.2		3.9
From System B											
16	825	0.0		0.0		0.3		0.3			0.2
30		0.0		3.5		18.6		17.9			16.0
50		63.0		91.0		78.6		79.3			80.9
70		31.0		5.3		2.3		2.5			2.7
Through 70 (Grain Size Index)		6.1		0.2		Trace		0.1			Trace
From System C											
16	2,450		0.0		0.0		0.6		12.0		
30			2.6		4.4		31.2		71.0		
50			51.5		41.9		37.4		10.6		
60			12.1		15.1		10.0		2.4		
70			8.9		10.6		7.3		1.4		
Through 70 (Grain Size Index)			22.6		26.1		12.1		0.9		
From System D											
16	133	1.7		5.1		8.4		23.8			31.8
30		86.0		86.5		85.5		72.4			64.0
50		11.0		6.0		4.4		2.8			3.4
60		0.6		0.7		0.4		0.3			0.5
70		0.2		0.4		0.2		0.1			0.2
Through 70 (Grain Size Index)		0.0		0.0		0.0		0.0			0.0

* U. S. Bureau Standards Screen Numbers.

it is 25, 50, etc., percent regenerated, and (c) the age of the zeolite, an index of which is the number of times it has been regenerated. These contentions are substantiated by the data in table XI which furnish information on the first two points, and by the data in table XII which furnish information covering the third point.

TABLE XI

Data Showing Cation Concentration of Effluent from Zeolite Softeners when Zeolite Was Immersed in Softened Water for Varying Lengths of Time*

	WATER SOFTENED AS PERCENT OF SOFTENER CAPACITY					WATER SOFTENED AS PERCENT OF SOFTENER CAPACITY					WATER SOFTENED	
	0.2	25	50	75	100	0.2	25	50	75	100	Samples Collected at Start of Cycle	
System Involved	A—Using Greensand—(A)					A—Using Greensand—(A)					D	D
Approximate Time Contact	4 min., i.e., during normal operation					5 days elapsed between regeneration and use					4 min.	500 days
Silica—SiO_2	3.4	3.3	2.3	2.4	1.5	17.0	14.8	11.1	4.3	3.6	3.2	30.5
Oxides—FeO_3—Al_2O_3	5.4	2.4	1.9	1.2	1.6	12.2	8.4	8.3	3.8	6.5	1.5	2.3
Calcium—Ca	1.1	1.2	0.4	0.8		1.8	1.4	1.3	0.7	2.9	0.6	4.4
Magnesium—Mg	1.7	0.5	0.5	0.9	2.9	1.1	2.0	2.0	0.2	2.0	0.3	1.4
Sodium—Na	44.7	45.8	46.1	46.4	45.0	44.5	45.6	44.8	45.9	45.1	45.3	41.4
Dissolved Solids	201	133	128	127	122	227	146	140	133	132	146	237

* All analytical figures are parts per million by weight.

TABLE XII

Average Cation Concentrations of Effluent from a Softener in System A upon Consecutive Regenerations

NUMBER OF CONSECUTIVE REGENERATIONS (APPROX.)	PARTS PER MILLION BY WEIGHT			
	SiO_2	Fe_2O_3 and Al_2O_3	Ca	Mg
50	2.4	1.8	3.1	1.2
100	3.8	0.7	0.8	0.2
350	3.8	2.2	3.5	1.3
400	2.6	3.1	1.9	1.8
1,150	6.7	8.1	2.7	1.8

No laboratory work has been done by the writer on the determination of the solubilities of zeolites. Data have been published, however, and those by Martin (47) are the most significant. These indicate two important things, (a) that at room temperature the quantity of silica put into the water by dissolution of the zeolite depends

upon the amount present in the influent and rarely exceeds fifteen parts per million in any case, (b) that the dissolution of most contemporary zeolites increases with temperature. It appears from Martin's data that no zeolite should be used with a water having a temperature above 85 F. Baker (14) has also published data which show that the dissolution of zeolites in carbonic acid solutions depends upon the CO_2 concentration. His results are somewhat astonishing.

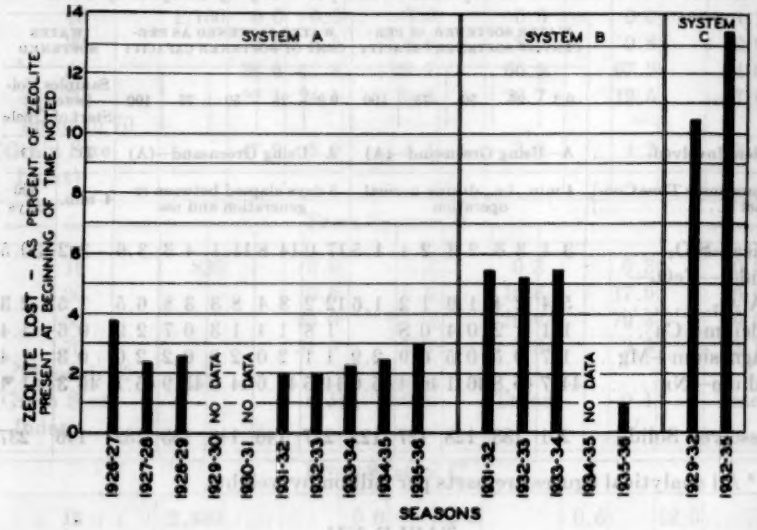

FIGURE 6. THE AMOUNT OF ZEOLITE LOST FROM A SOFTENER IN SYSTEMS "A, B" AND "C" DURING THE TIME INTERVALS NOTED.

Some Practical Effects of Attrition and Dissolution

One obvious effect of disintegration and dissolution of zeolite is a loss of the material from a softener. In Systems A, B, and C the amount of zeolite lost from one unit for various time intervals is shown graphically in figure 6.

Formation of Silicate Scale. The data in figure 6 are believed to have more importance in boiler water treatment than the mere indication of a loss of zeolite. It was found, for example, that when the water contained an amount of silica about equal to that shown by the last analysis in table XII a small amount of silicate scale was deposited within the boilers in system A. An analysis of two samples of this scale gave the results shown in table XIII.

When this scale was formed, the treating scheme had been altered by eliminating the addition of phosphoric acid following zeolite. It is possible that the presence of phosphate would have prevented its formation. The fact that Hall (48) has obtained a patent for the

TABLE XIII

Analyses of Scale Taken From a Boiler in System A

CONSTITUENTS	SAMPLES TAKEN FROM	
	Head of Front Drum	A Tube in Front Pass
	percent	*percent*
Silica—SiO_2	34.35	33.62
Oxides—Fe_2O_3 and Al_2O_3	16.32	19.80
Calcium Oxide—CaO	38.33	34.38
Magnesium Oxide—MgO	1.19	0.99
Sulphur Trioxide—SO_3	1.97	1.07
Carbon Dioxide—CO_2	6.00	10.00
Moisture Lost @ 105 c	0.50	0.42
Total	98.66	100.28

TABLE XIV

*Statistics of Reprocessing Operation**

NATURE OF TREATMENT	CHEMICAL USED	STRENGTH OF SOLUTION, PER-CENT	VOLUME OF SOLUTION USED, POUNDS	TEMP. OF SOLUTION, DEG. F.	TIME OF CONTACT WITH TREATING SOLUTION, HOURS
First Regeneration	NaCl	5	8,000	40	0.5
Second Regeneration	NaCl	10	8,000	40	2
Third Regeneration	NaCl	10	8,000	40	12
Scouring	NaOH	3	15,500	212	1
Rehabilitation	Na_2SiO_3	7	15,500	212	1
Restabilization	$Al_2(SO_4)_3$	4	15,500	40	1

* These data pertain to the reprocessing of 200 cubic feet of zeolite.

prevention of such scales following zeolite suggests that such troubles must have occurred elsewhere.

Restabilization of Greensand. It seems evident that continued use of zeolites tends to remove silica slowly from the grains. This

makes the grain more susceptible to mechanical wear. For boiler water treatment purposes, it appears that after about 1500 regenerations or five years of service it would be advisable to retreat most contemporary greensands in an effort to make them more resistant

TABLE XV

Cation Concentration of Effluent From a Greensand Softener Before and After Reprocessing Zeolite

PARTS PER MILLION OF	SYSTEM INVOLVED	RAW WATER	WATER SOFTENED AS PERCENT OF SOFTENER'S CAPACITY				
			0.2	25	50	75	100
Before Reprocessing*							
Silica—SiO_2	A	3.8	8.3	8.3	7.4	6.1	5.1
Oxides—Fe_2O_3—Al_2O_3		3.3	5.6	19.0	4.6	5.1	3.6
Calcium—Ca		25.9	0.6	1.4	1.3	0.6	7.5
Magnesium—Mg		6.3	0.8	1.4	0.4	0.9	4.8
Sodium							
Dissolved Solids		120	151	140	135	134	109
Immediately After Reprocessing							
Silica—SiO_2	A	0.8	7.3	4.7	5.9	6.5	3.8
Oxides—Fe_2O_3—Al_2O_3		0.7	1.5	0.9	0.6	1.2	1.0
Calcium—Ca		27.8	0.6	0.2	0.4	0.5	7.0
Magnesium—Mg		7.4	0.3	0.1	0.4	0.4	3.1
Sodium							
Dissolved Solids		111	170	138	139	132	120
One Year after Reprocessing							
Silica—SiO_2	A	1.2	0.7	0.9	2.7	2.7	0.4
Oxides—Fe_2O_3—Al_2O_3		1.2	3.2	2.6	0.7	0.8	0.4
Calcium—Ca		26.9	3.9	3.1	1.9	0.8	18.1
Magnesium—Mg		7.4	1.2	0.6	0.4	0.3	7.0
Sodium—Na							
Dissolved Solids		116	158	143	128	123	109

* Zeolite had been regenerated more than 1150 times before these analyses were made.

to disintegration. This was done with all the zeolite in systems A and B, about 3500 cubic feet. In table XIV the quantity of chemicals, strength of solutions, etc., that were used to treat a batch of 200 cubic feet of zeolite are recorded.

The data in table XV show the cation concentration of the same

water after having been softened by the same zeolite just preceding restabilization, immediately following retreatment, and one year thereafter. The high silica content of the samples immediately following restabilization may have been due to excess silica not removed from the grains by the rinsing operation during the treatment. The writer has heard of no honest attempts being made to restabilize a synthetic zeolite.

Pressure Losses and Bed Expansions. From a mechanical standpoint the question of attrition and therefore of grain size is of different degrees of importance depending upon the type of softener

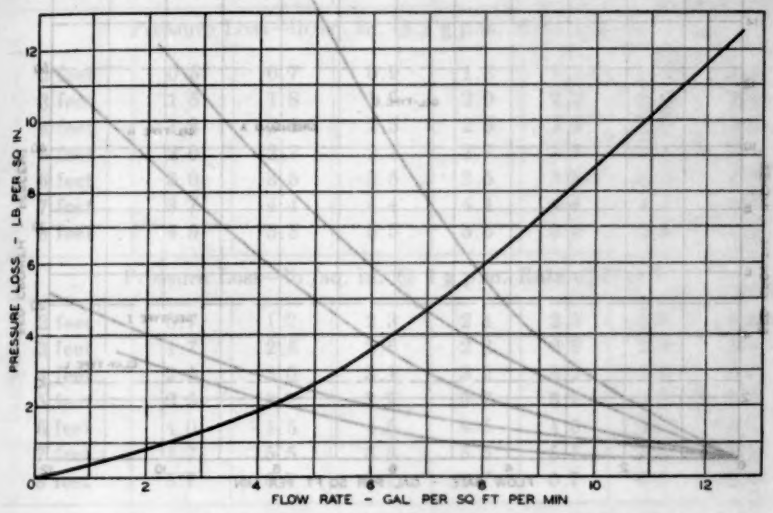

FIG 7 CURVE SHOWING THE PRESSURE LOSS THROUGH A 39 INCH BED OF GEL-TYPE G (10-48 MESH) AS A FUNCTION OF FLOW RATES

used. Softeners are constructed to operate either in an "upflow" or "downflow" direction. In the latter case grain size probably is of less importance than in the former. In downflow operation the chief item of concern is the increase in pressure loss brought about by continual packing of the bed. For greensands of the usual grain size uniformity, the pressure losses which may be anticipated for various depths of zeolite as a function of time and water velocities are given in table XVI on the following page. Comparable data for synthetic zeolites are not available.

For Gel-synthetic-G, the manufacturer has given the curve, shown in figure 7, as a measure of the pressure loss with this zeolite.

With respect to these data he states: "The curve is plotted from actual tests on a 30-inch diameter softener with 16-inch gravel bed and a 39-inch bed of (10–48 mesh) zeolite." This relationship probably holds true for most synthetics of a comparable grain size range.

In upflow systems, experience has pretty well demonstrated that a minimum and maximum rate of flow exists for each zeolite. Between these limits the zeolite is put into partial suspension and this assures uniformity of contact with the water. Figure 8 shows the extent to which some zeolite beds expand when water is passed up-

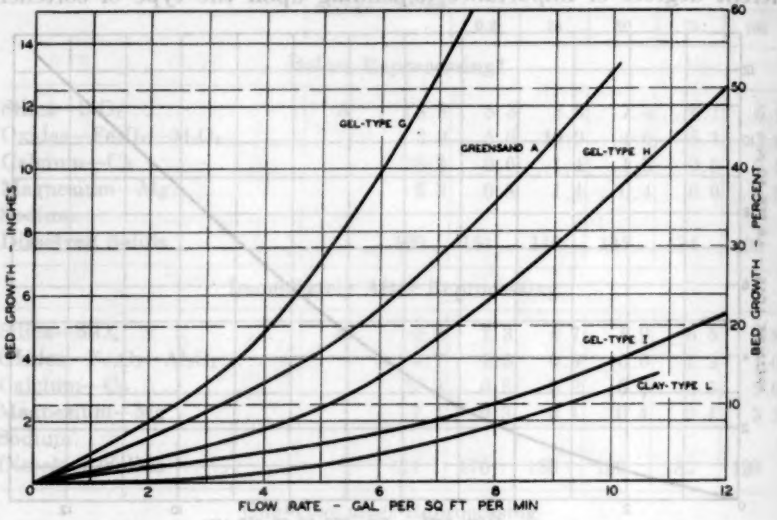

FIG 8 CURVES SHOWING THE BED EXPANSION OF DIFFERENT ZEOLITES AS A FUNCTION OF "UP" FLOW RATES

ward at different velocities. It will be noted that in no case do the beds of zeolite expand as a linear function of the velocities. A feasible explanation of this seems to be the lack of uniformity in grain size. That this is true seems evident from the fact that those products which are processed to fairly uniform size demonstrate a more pronounced tendency to approach the straight line function than do others. Armstrong (49) detected this same correlationship in studying the expansive properties of filter sand. It should be obvious that the data in figures 7 and 8 and in table XVI hold true for new zeolites and not for those made finer by prolonged use.

Loss of Softening Capacity

The primary object for using a zeolite is to remove as much calcium and magnesium from the water as is possible. The amount of calcium and magnesium which a unit quantity of zeolite will absorb is referred to as its (the zeolite's) exchange capacity. In figure 9 is shown graphically the exchange capacity which four different zeolites exhibited in actual service.

TABLE XVI

Pressure Losses in Pounds per Square Inch Through Greensand Exclusive of Gravel, Strainer System and Exterior Piping

BED DEPTH	AT START	NUMBER OF HOURS AFTER REGENERATION					
		1	2	3	4	5	6 and up
Pressure Loss—lb/sq. in. @ 3 g.p.m. Rate of Flow*							
2 feet	0.5	0.7	0.9	1.5	1.7	1.8	2.0
3 feet	1.5	1.8	1.9	2.0	2.2	2.2	2.2
4 feet	1.8	2.5	2.5	2.5	2.5	2.5	2.5
5 feet	2.0	2.7	2.7	2.7	2.7	2.7	2.7
6 feet	3.0	3.5	3.5	3.5	3.5	3.5	3.5
7 feet	3.7	4.4	4.4	4.4	4.4	4.4	4.4
8 feet	4.5	5.5	5.5	5.5	5.5	5.5	5.5
Pressure Loss—lb./sq. in. @ 4 g.p.m. Rate of Flow*							
2 feet	0.7	1.7	2.3	2.4	2.5	2.6	2.6
3 feet	1.7	2.5	2.6	2.8	2.9	2.9	2.9
4 feet	2.5	3.0	3.1	3.2	3.2	3.2	3.2
5 feet	3.5	3.7	3.7	3.7	3.7	3.7	3.7
6 feet	4.0	4.5	4.5	4.5	4.5	4.5	4.5
7 feet	4.7	5.5	5.5	5.5	5.5	5.5	5.5
8 feet	5.7	6.7	6.7	6.7	6.7	6.7	6.7
Pressure Loss—lb./sq. in. @ 5 g.p.m. Rate of Flow*							
2 feet	1.0	2.3	2.4	2.5	2.7	2.8	2.9
3 feet	2.1	3.0	3.1	3.1	3.2	3.3	3.3
4 feet	3.0	3.7	3.7	3.7	3.7	3.7	3.7
5 feet	3.7	4.5	4.5	4.5	4.5	4.5	4.5
6 feet	5.0	5.5	5.5	5.5	5.5	5.5	5.5
7 feet	6.0	6.0	6.6	6.6	6.6	6.6	6.6
8 feet	7.3	8.0	8.0	8.0	8.0	8.0	8.0

* Per square foot of bed area.

These curves point out two characteristics that invariably attend

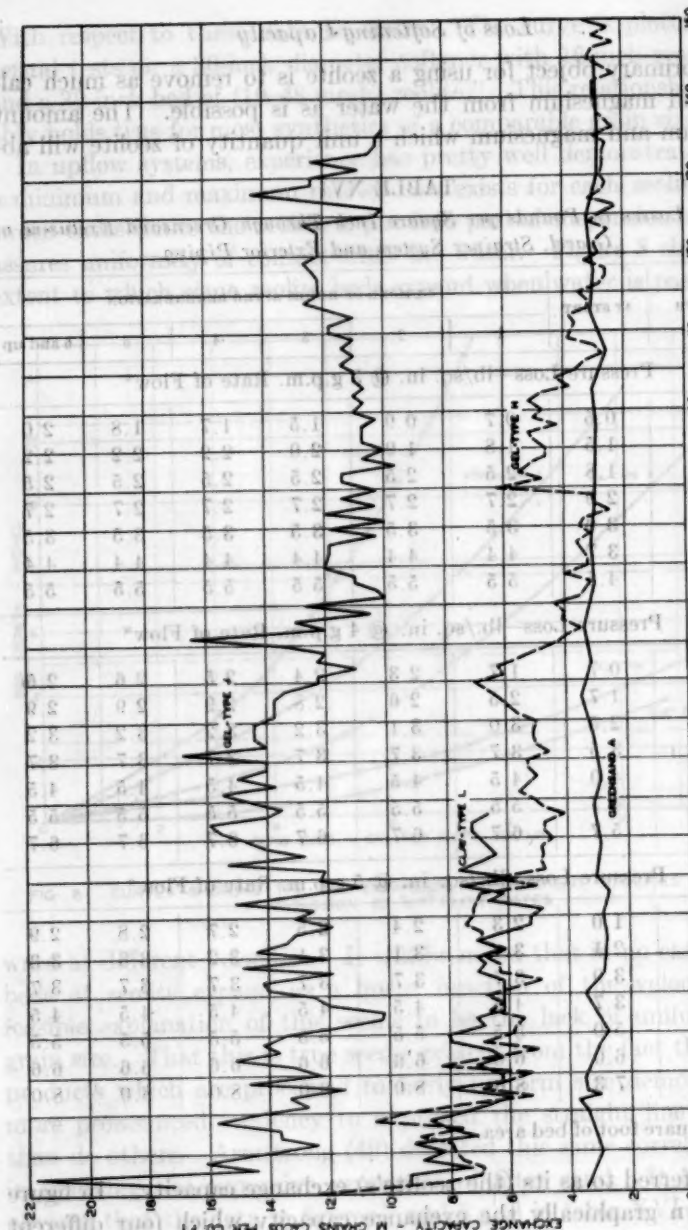

FIG. 9 EXCHANGE CAPACITY EXHIBITED BY FOUR DIFFERENT ZEOLITES IN ACTUAL OPERATION

the performance of zeolite softeners, (a) a lack of consistency in the exchange capacity upon consecutive regenerations, and (b) a gradual but nevertheless definite decrease in exchange capacity with continued use. The former is unquestionably due, *in part*, to a lack of sensitivity on the part of the method used in obtaining such data, whereas the latter apparently is due to the cumulative effect of several factors among which the following are prominent:

1. The physical and chemical conditions of the zeolite grains.
2. The temperature of the influent.
3. The rate at which water is passed through the zeolite.
4. The amount of salt used and the uniformity of distribution of the brine during regeneration.

Influence of Physical and Chemical Conditions of the Zeolite. When the physical condition of a zeolite is mentioned, it is quite natural for one to visualize relative grain size. There is no good reason why a given grain should grow during service and yet by comparing the capacity curves in figure 9 with the grain size indices in table IX one is led to the erroneous conclusion that exchange capacity decreases with a decrease in grain size. Coincidentally the data do indicate this trend, but it is well known that for synthetic zeolites, at least, the exchange capacity increases with a decrease in grain size. It is probable in the case of the data cited above that the pores of the zeolites had become slowly plugged with foreign matter at a rate somewhat in proportion to the rate at which the grains were wearing smaller, and that the decrease in effective surface produced by the former cause was responsible for the decrease in capacities found. That foreign matter was deposited upon these zeolites is indicated by the increase in the iron and alumina content of the used materials. This is shown by the data in table XVII. In connection with these data it is also to be noted that silica was lost from all these zeolites upon use.

Effect of Influent Temperatures. It has been noted that with greensand softeners the exchange capacity is consistently higher in warm weather than in cold even though there is no change in the chemical composition of the influent. Such units show an increase of approximately 10 percent in exchange capacity for water at 70°F. as compared to a temperature of 33°F.

It seems to be generally true for most zeolites. In the case of Gel-Synthetic-I for instance, it has been reported that the exchange capacity is almost trebled by an increase in temperature from 100°F. to 200°F.

Martin (47) attributes the effect of increased temperature to the fact that the viscosity of the solution becomes less with increased temperature. The solution (water), he opines, is better able to enter the capillary channels increasing both the amount and the speed of the base-exchange reaction.

Rarely, however, can this advantage of increased temperature be utilized. The solubility of most zeolites increases with temperature, and silica so put into solution is capable of causing serious troubles

TABLE XVII

Chemical Analyses of New and Used Zeolites—Percent

TYPE OF ZEOLITE	SYSTEM INVOLVED	NUMBER OF REGENERATIONS	SILICA SiO_2	OXIDES, IRON AND ALUMINA	LIME—CaO	MAGNESIA—MgO	SODA AND K AS NaO	LOSS ON IGNITION
Greensand—A		None	48.49	32.28	1.60	4.19	6.79	6.69
"	A	115	48.14	37.48	0.72	3.30	3.41	6.95
Greensand—B		None	48.80	31.00	1.40	4.11	7.81	6.88
"	B	825	47.34	37.54	1.74	1.96	4.83	6.59
Gel-Synthetic—H		None	63.32	11.12	0.20	0.64	9.90	14.82
"	C	2,450	48.12	21.06	0.40	1.17	6.48	22.72
Gel-Synthetic—J		None	57.44	17.60	0.86	0.58	6.65	16.87
"	D	165	50.88	27.88	0.80	1.08	4.90	14.46
Bentonitic Clay—L		None	58.20	26.58	1.15	2.70	3.96	7.41
"	E	200	40.12	34.44	2.96	1.72	6.00	14.76
Gel-Synthetic—I		None	55.96	20.44	0.68	0.17	4.95	17.80
"	F	400	52.54	23.40	0.68	1.03	3.31	19.04
"	G	500	54.32	23.44	1.24	1.99	3.54	15.47

especially within steam boilers. Then, too, there is the added danger, if a temporary hard water is being softened, of depositing calcium carbonate upon the zeolite grains.

Effect of Varying Water Velocities. With respect to the exchange reaction, it will be recalled, theory holds that (a) the exchange takes place on the surface of the grains where it is almost instantaneous but (b) in porous zeolites the reaction rate is somewhat dependent upon the rate at which sodium diffuses outward to the surface. If

this be true then it should follow that the exchange capacity of a dense zeolite will be little affected by varying water velocities, whereas, the exchange capacity of a porous zeolite should vary inversely with the water velocity. Further, it should follow that if water of a given hardness is passed through different zeolites at the same rate of flow, the hardness of the effluent, at the end of the softening cycle, should increase rapidly with a dense zeolite (as for

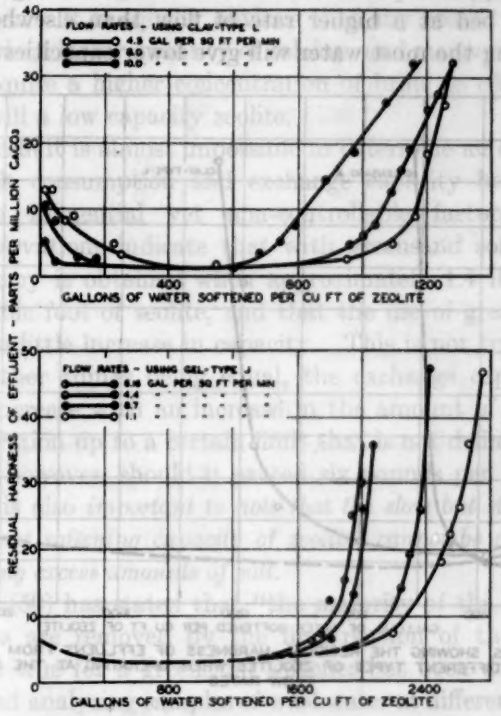
FLOW RATES - USING CLAY-TYPE L
4.3 GAL PER SQ FT PER MIN
8.0
10.0
RESIDUAL HARDNESS OF EFFLUENT - PARTS PER MILLION CaCO3
GALLONS OF WATER SOFTENED PER CU FT OF ZEOLITE
FLOW RATES - USING GEL-TYPE J
6.6 GAL PER SQ FT PER MIN
4.4
8.7
11
RESIDUAL HARDNESS OF EFFLUENT - PARTS PER MILLION CaCO3
GALLONS OF WATER SOFTENED PER CU FT OF ZEOLITE

FIG 10 CURVES SHOWING THE RESIDUAL HARDNESS OF EFFLUENT FROM A BENTONITIC CLAY AND A GEL-TYPE SYNTHETIC SOFTENER OPERATING AT DIFFERENT FLOW RATES

example a greensand) and more gradually with the porous types. Data to substantiate the first assumption are shown in figure 10 for two porous zeolites. Tests conducted with greensand softeners show no pronounced change in capacities for flow rates up to 10 gallons per square foot of bed area per minute which incidentally is the maximum rate at which an unflow softener may be operated without entraining fine zeolite. Data to cover the second assumption are

shown in figure 11 for a greensand, a gel type synthetic and a clay type zeolite.

But, even though no measurable effect of velocity was detected in the case of the greensand, it is believed, nevertheless, that some small influence is exerted. This would help to explain the small fluctuations in exchange capacity which normally attend the operation of such softeners upon consecutive regenerations. In large units especially, it is possible for water to flow through some portions of the bed at a higher rate of flow than elsewhere. Those parts receiving the most water will give lower capacities than under

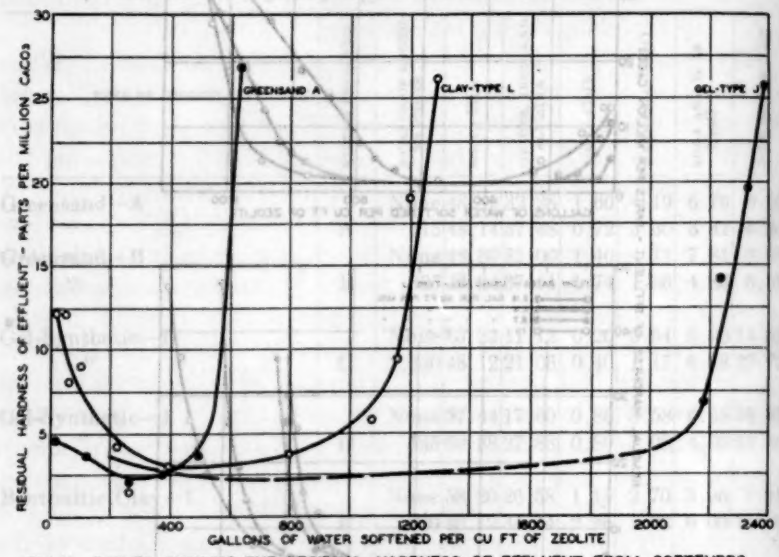

FIG 11 CURVES SHOWING THE RESIDUAL HARDNESS OF EFFLUENT FROM SOFTENERS USING DIFFERENT TYPES OF ZEOLITES WHEN OPERATING AT THE SAME FLOW RATES

normal conditions, and the net result alters the total capacity of the softener. This would not occur necessarily each time the softener is regenerated, nor to the same extent, but would nevertheless be influential.

Effect of Salt Used in Regeneration. In regenerating a zeolite the reactions involved are the reverse of those taking place during the softening operation. It will be recalled that some of the premises laid down with respect to the base-exchange reaction were, that the exchange of one base for another is *never* complete but proceeds until equilibrium has been established, that the latter depends upon the concentration of base ion (in the case of the regeneration reaction of

sodium) in the water, and that chemically equivalent amounts of bases are exchanged.

A moment's reflection will show that any zeolite which has softened a large amount of water has, by this very fact, absorbed a relatively large amount of calcium and magnesium. If this amount of calcium and magnesium, which it has taken hours for the zeolite to absorb, is to be released in a short regenerating period (which practical operation demands), a large amount of sodium must be added in the brine solution. It is equally obvious that any zeolite (a synthetic) which absorbs a larger quantity of calcium and magnesium per cubic foot will require a higher concentration of brine to effect regeneration than will a low capacity zeolite.

In field tests it is almost impossible to determine an exact relation between salt consumption and exchange capacity because of the presence of influential yet non-controllable factors. However, general observations indicate that with greensand softeners maximum efficiency is obtained when approximately 1.4 lb. of salt are used per cubic foot of zeolite, and that the use of greater amounts of salt cause little increase in capacity. This is not true for porous zeolites. Other things being equal, the exchange capacity of the latter will increase with an increase in the amount of salt used for each regeneration up to a certain limit that is not definitely defined. In no case, however, should it exceed six pounds per cubic foot of zeolite. It is also *important to note that the slow but steady decrease in the inherent softening capacity of zeolites cannot be completely arrested by using excess amounts of salt.*

Partridge (50) has stated that "the majority of the hardness imparting salts are removed by the first portion of the brine. . . ." That this is true for a greensand softener has been determined by collecting and analyzing samples of washwater at different stages during its regeneration. The result obtained are shown in table XVIII. In the unit from which these data were collected, a saturated brine was first introduced and was subsequently forced downward through the bed by adding fresh water. This method of regeneration is often criticized. It is claimed that the brine introduced should be approximately a five percent solution in order to obtain maximum regeneration. The data in column one of table XVIII indicate that, in the softener investigated, a brine of the approximate recommended strength was obtained without resorting to cumbersome mixing equipment. It is to be noted further that the majority of the hardness is removed by the first portion of brine, that the purity of the

TABLE XVIII

Concentration of Chlorides in Effluent During Regeneration of a Large Greensand Softener in System A

GRAMS/100 GR. H_2O		NaCl / $CaCl_2$*	WASH WATER USED**
NaCl	$CaCl_2$		
3.9	3.05	1.27	31
4.6	3.05	1.51	34
5.1	2.73	1.87	35
5.4	2.31	2.34	36
5.1	1.72	2.96	39
4.1	1.52	2.70	40
3.6	0.59	6.10	42
2.6	0.52	5.00	44
1.3	0.19	6.85	47
0.6	0.04	15.00	50
0.4			53
0.2			56
0.1			63

* $CaCl_2 + MgCl_2$ as $CaCl_2$.

** As percent of total quantity of wash water required.

TABLE XIX

Upflow Regeneration vs Flow Rates vs Exchange Capacity

TEST NUMBER	FLOW RATE*	EXCHANGE CAPACITY**	SALT USED***
	Bentonitic Clay—L (System E)		
1	2	8,000	3.75
2	4	4,650	3.75
3	4	4,850	7.50
4	6	3,500	3.75
5	7	2,900	3.75
6	7	2,500	3.75
	Greensand—A (System A)		
1	1.2	3,160	2.39
2	1.2	3,200	3.23
3	1.6	2,745	2.39
4	2.0	2,570	2.39
5	2.0	2,540	1.54
6	4.0	1,520	2.39

* Gallons per minute per square foot of bed area.

** Grains of $CaCO_3$ per cubic foot of zeolite.

*** Pounds per cubic foot of zeolite.

brine ($NaCl/CaCl_2$) increases as regeneration proceeds. Thus, even though the salt content is decreasing the increased purity guarantees a vigorous removal of hardness. Finally, it is to be noted that the low concentration of sodium chloride in the last portion of the wash water does not argue well for the economics of salt saving devices which are frequently advocated for retrieving the last one-third of the wash water.

Regardless of the strength of brine solution used, it is a universal custom to regenerate zeolite softeners by first introducing the brine into the top of a softener and then to wash it downward through the bed. It has never been quite clear why equally good results could not be obtained by putting the brine through in the reverse direction. However, tests conducted with a clay type, and a greensand softener indicate that upflow regeneration is not satisfactory. Complete regeneration, it was found, could not be obtained unless a large excess of salt was used, and even then the exchange capacity was found to be proportional to the rate at which the salt was washed out. Table XIX shows the data obtained. Perhaps poor distribution is the difficulty.

GENERAL SUMMARY

It has been demonstrated that contemporary zeolites can be classified primarily upon the basis of their chemical composition, that those of a given class exhibit no radical differences in characteristics due to the methods of processing used, and that all are somewhat limited in their ability to treat waters for industrial purposes. Their limitations have been shown to revolve around (a) their susceptibility to disintegration due to attrition and disintegration, (b) their inability to exhibit a stable exchange capacity, (c) that their use sometimes accelerates corrosion in an otherwise inert water and (d) that the design of softeners, utilizing gravel beds, is not entirely satisfactory for industrial purposes.

It seems unlikely that all of these limitations will be eliminated for some time to come, but an alleviation of major troubles may be effected if the following precautions are observed in connection with the operation of large units.

1. To prevent gravel bed disruption, a completely drained unit should never be filled by introducing water at the bottom at a rate of flow in excess of two gallons per square foot of bed area per minute. This rate should not be exceeded for at least five minutes after water emerges from the outlet line. It is also advisable to use a modified

form of this rule when putting a softener already filled with water into operation.

2. It is advisable once annually to flush the bed with chlorinated water in an effort to destroy bacteriological growths.

3. A regenerated zeolite softener that is not operating should never be left full of water for a period of more than ten hours.

4. When a softener is to be decommissioned for a period of one week or longer the zeolite should be in the *unregenerated* state and the unit should be completely drained. For synthetic softeners, the zeolite should not be allowed to become dry—it should be kept damp but not submerged.

5. The salt used for regeneration should contain at least ninety-six percent sodium chloride, should be free of iron, mud, chips, etc. Rock salt of the following analysis has been used satisfactorily since 1928 with six large greensand softeners.

Analysis of Rock Salt—System A

	Percent
Moisture (Loss @ 105 C)	0.03
Water insolubles (SiO_2, Fe_2O_3 and Al_2O_3)	0.39
Calcium sulphate	1.19
Calcium chloride	0.22
Magnesium chloride	0.19
Calcium phosphate	Trace
Sodium chloride	98.29

6. A zeolite softener is not satisfactorily regenerated if the chloride content of the first ten percent of the water softened (per regeneration) is ten parts per million higher than in the influent. The chloride content of the effluent and the influent should be identical during the last ninety percent of the softening run.

7. The total hardness (as $CaCO_3$) of the water used for washing during regeneration should not exceed ten grains per gallon.

8. When used to soften water for boiler use the influent to a softener should never be treated with a soluble silicate (to prevent dissolution of the zeolite) nor is it advisable to acid-treat the influent.

9. A zeolite softener should never be used in connection with a water which is definitely acid or caustic in character.

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OBSERVATIONS ON ZEOLITES IN WATER SOFTENING AND DEMANGANIZATION*

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Inventions and discoveries are seldom adopted overnight. A recent government publication (1) states "From the early origins of an invention to its social effects the time intervals average about 30 years." This is strikingly true of the use of zeolite in water softening. The early conception of base exchange was discovered in 1852, but its applicability to water softening was not recognized until much later by Dr. Robert Gans, to whom a patent was issued in 1906. Within twenty years there had developed a very considerable use of zeolite, both natural (green sand) and synthetic in commercial applications, such as for laundries, steam boiler plants and for homes.

EARLY MUNICIPAL PLANTS

It is believed that the first application of zeolite to municipal softening was made at the plant of the Ohio Valley Water Company in 1926 (2). This plant serves a group of suburbs comprising about 60,000 inhabitants, on the Ohio River just below Pittsburgh. It has a capacity of 4,000,000 gallons per day, and is of the down-flow pressure type in four separate horizontal units, each 9 feet in diameter by 25 feet in length, employing green sand as the softening medium. A 2,000,000 gallon open gravity type of softener was put into service at Sewickley, Pa., in 1929. In the past ten years zeolite has found increasing favor and such plants are in operation in all parts of the country.

At present the greater part of the population (about 106,000) bordering on the Ohio River for a distance of twenty miles below Pittsburgh is served by five zeolite softening plants. To all intents they serve as practical, working laboratories for observation and experiment and, over the years, answers have been given to many

* Presented at the Central States Section meeting, August 20, 1937.

problems concerning the action of zeolite in water softening, which were not wholly clear in the early days. It is proposed in this paper to touch briefly on some of these questions.

UNDERGROUND WATER SUPPLIES

Although the Ohio River flows by the plants, the high contamination from the Pittsburgh area has counseled other sources of supply than the river. Abundant underground water is available in the deposits of sand and gravel left by the old glacial river in the partly filled rock cut gorge of the old stream bed. These waters are clear, generally pure, fairly hard and carry a comparatively high percentage of sulphates.

ADVANTAGES OF ZEOLITE

Such waters are ideally adapted to the use of zeolites since they are free of turbidity, do not require filtration and the costs for hardness reduction are low, since sulphates can be more economically removed by salt in zeolite base exchange than by soda ash as would be employed in a lime-soda type of plant. The first costs of zeolite plants are likewise less than for lime-soda plant since mixing chambers and mechanism, clarifiers and sedimentation basins are not required and the means for salt storage and application are much simpler and less expensive than for lime and soda installations.

PLANT OPERATION

It may be well to review briefly the essential features and operation of a zeolite plant. The hard water, containing calcium and magnesium, is passed through the zeolite bed in an upward or downward direction until such time as the sodium content of the zeolite has become exhausted by base exchange. The water delivered from the unit has no lower content of solids than originally, but is "soft" in that sodium has replaced the "hard" elements of calcium and magnesium. The zeolite bed, when "exhausted," is "regenerated" by passing a solution of sodium chloride through the softener, which results in a reversed base exchange, leaving the zeolite with its initial sodium content and ready for further service, after the resulting products of exchange and excess salt have been rinsed out through the sewer. This process can apparently be continued indefinitely without diminution of capacity in the zeolite except as it is impaired by mechanical abrasion and loss.

PLANT TYPES

Three of the plants in the Pittsburgh district are of the open gravity type, and two are of the pressure type, one of which is operated automatically. All function as down-flow softeners and green sand or glauconite is the softening medium. The sands have been supplied by several different processors and appear to have practically identical physical and base exchange characteristics.

EXCHANGE CAPACITY

Many manufacturers guarantee about 2,800 grains of hardness removed per cubic foot of mineral when regenerated with $\frac{4}{10}$ pound of salt per thousand grains of hardness removed, and on the basis of approximately a 12 grain water. This guarantee is quite conservative, for the results usually run from 3,000 to 4,000 grains for ordinary green sand at these plants. Considerable variation occurs between runs, the reason for which baffles discovery. But it is probably due to channeling so that the entire bed does not reach complete exhaustion.

Increase in hardness tends to reduce the exchange capacity to some extent. At Sewickley for the first year's operation, the best exchange was about 3,900 grains per cubic foot (to complete exhaustion) at 9.5 grains hardness, and reduced to 3,750 when the hardness was 15.5 grains. The alkalinity of the water remains in the near neighborhood of 6 grains, so that the increase in hardness is largely of the non-carbonate type, which evidently has an adverse effect on exchange. After about five years the capacity at this plant began to diminish and while in the first year (1929) it averaged 3,840 grains, in 1936 it had reduced to 2,900 grains. During back-washing it was noted that some areas in the bed just above the gravel failed to rise, indicating uneven distribution of wash water. The 18-inch bed of gravel was found to have been upset in places, and consequently the beds were rebuilt. When the gravel was regraded and replaced the entire sand bed rose uniformly as at the start of operation in 1929, and the exchange capacity of the sand returned to about 3,400. If good exchange values are to be maintained it is imperative that the entire sand bed be kept loose and free so that there is no channeling, and that all the sand grains contribute their share to the softening action.

DEEP GRAVEL BEDS VERSUS SCREENS

In an effort to correct this upsetting of the gravel and the consequent tendency to channel and by-pass the water as it passed down through the sand bed, it was decided at Edgeworth to substitute a 10-inch graded gravel bed, held down by a gravel screen, instead of 18 inches of graded gravel as at Sewickley. This was occasioned by reports of results on filters of these characteristics at Erie, Pa., where the screened filters gave a much better account of themselves than did the filters with the deep gravel bed. The Edgeworth plant has been in operation for only nine months—too short a time to test results; but the bed conditions appear as good now as on the first day's operation. Incidentally, at none of the plants have mud balls put in an appearance.

LOSS OF ZEOLITE

Sand loss appears to be due to departure of "fines" over the wash trough due to the abrasion of the sand at back wash periods. This factor has not been serious and in the gravity plants has averaged less than 2 percent per year. The early closed filters have suffered somewhat greater loss since they were of the horizontal type, and velocity of wash water tended to increase as it was pinched in while approaching the off-take pipe at the top of the cylinders. Wash rates had to be limited to about 5½ gallons per square foot per minute to avoid loss and channeling.

CRENOTHRIX

Because of the manganese in solution, crenothrix is encountered at each plant, but is more prevalent at the old Ohio Valley Water Company pressure plant and at the Sewickley gravity plant than at the others. At the first plant water is derived from wells but passes into a pit beneath the low service pumps in which the wood forms and staging had been left intact and which supported the crenothrix growth. At Sewickley the crenothrix grows on the wooden timbers forming the river crib from which the ground water is derived. This growth occasioned considerable annoyance and trouble at the pressure plant in the early years since it tended to stick in the sand, forming a yellow liver-like loblolly that looked as though soaked with yellow ochre. It was the devil's own job to get into these units through a small manhole and eject the sand out and in for the purposes of giving it a thorough scrubbing. The ap-

plication of chlorine to the raw water at the rate of 0.7 p.p.m. effectively controlled the situation and the sand now remains perfectly clean continuously.

At Sewickley, during the drouth of 1930, the manganese and hardness jumped up precipitously and the crenothrix seemed to multiply and thrive at the expense of the plant's adversity, until it came over in long strings and formed a mat on the sand surface that could not readily be washed out even with a 24-inch rise of wash water (more would have washed out the sand). Screening the sand with an improvised hand screen during back-washing helped, but, even so, the surface packed and developed cracks which produced channels and a consequent reduction in the exchange capacity and increase in the salt rate. With the return of the rains this condition cleared up and has given no trouble since. The crenothrix is more prevalent in summer than winter, possibly because the manganese increases during the warm and dry weather.

SALT DOSE

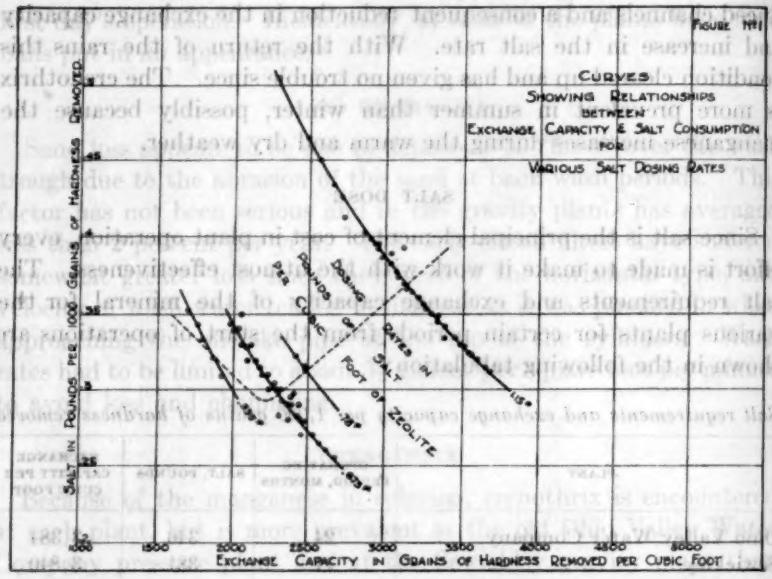
Since salt is the principal element of cost in plant operation, every effort is made to make it work with the utmost effectiveness. The salt requirements and exchange capacity of the mineral for the various plants for certain periods from the start of operations are shown in the following tabulation:

Salt requirements and exchange capacity per 1,000 grains of hardness removed

PLANT	OPERATING PERIOD, MONTHS	SALT, POUNDS	EXCHANGE CAPACITY PER CUBIC FOOT
Ohio Valley Water Company	24	.346	3,384
Sewickley	11	.381	3,840
Edgeworth	9	.341	2,813
Ambridge	Dec. 1935	.36	3,250
Coraopolis	July 1937	.377	2,280
Edgeworth	July 1937	.297	2,349

At the Edgeworth plant some studies were made to determine the optimum salt dosage with results as depicted in figure 1. This shows that the salt efficiency can be increased if the exchange capacity of the mineral is reduced. In the practical operation of that plant this meant that when 590 pounds of salt were used to regenerate 515 cubic feet of sand, it was possible on the average to soften

136,000 gallons of 12 grain water per run; or at an expenditure of about 0.36 pounds of salt per thousand grains of hardness removed. By reducing the dose to 350 pounds, only 99,000 gallons per run could be softened but the salt rate dropped to 0.3 pound per thousand grains of hardness removed, which represents a saving of about 17 percent in salt. During periods when the raw water is below the average in hardness, this maneuver may be justified since the runs may be amply long in any case and the cost of the additional wash and rinse water required will be considerably less than the salt savings.

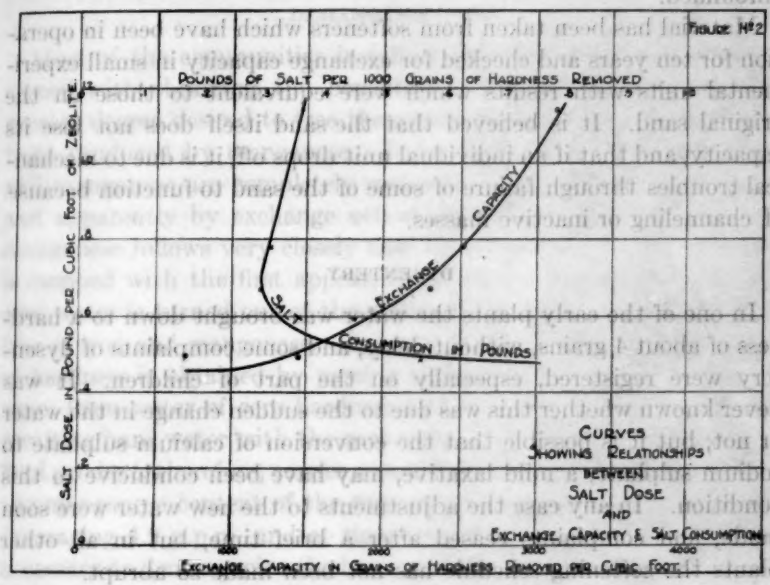


These facts may be presented in another form (figure 2) indicating the relationships between the three salient factors. It would appear that for this water the optimum condition would be achieved by a dosage of about 0.70 pounds of salt per pound of zeolite, which represents about 0.3 pounds of salt per 1,000 grains of hardness removed and an exchange capacity of about 2,400 grains per 1,000 grains of hardness removed.

Hardly less important than the salt dose in developing the best efficiency from the salt, is the rate at which it is passed through the bed. Considerably better results will be obtained if the rewash

valve is opened to permit a one gallon per square foot per minute rate through the softener than is had at the three gallon rate, at least for the first few minutes, to be followed by rinsing at full open valve.

Continued softening through zeolite apparently has no effect on the salt rate. In support of this statement is the experience at Sewickley, which showed an average rate of 0.381 pounds of salt per 1,000 grains of hardness removed for the first eleven months operation in 1929, as compared to 0.381 pounds for the past four months ending July 31, 1937.



BACK WASHING

If it were only necessary to back wash at such times as the loss of head through the mineral had built up to a point requiring the lossening of the sand, this operation would have to be undertaken only once in several regenerations. However, it has been found desirable and economical to back wash before each regeneration, since the runs are longer and the salt rate better. At Ambridge, where the manganese averaged 4.9 p.p.m. this wash brought up a cloud of deep reddish brown material which apparently clung to the surface of the grains throughout the entire zeolite bed. Evi-

dently this film requires removal if the salt is to have the best access to each individual sand grain.

"STARVING" OF ZEOLITE

In some of the plants it is the custom to run the softeners past the point where hardness first appears, and to carry the process to the complete exhaustion of the mineral; that is, until completely hard water passes through the units. This practice was formerly discouraged by some suppliers of zeolite, but the facts indicate that the fear of deterioration in the exchange capacity of the sand was unfounded.

Material has been taken from softeners which have been in operation for ten years and checked for exchange capacity in small experimental units with results which were equivalent to those on the original sand. It is believed that the sand itself does not lose its capacity, and that if an individual unit drops off, it is due to mechanical troubles through failure of some of the sand to function because of channeling or inactive masses.

DYSENTERY

In one of the early plants the water was brought down to a hardness of about 4 grains, without delay, and some complaints of dysentery were registered, especially on the part of children. It was never known whether this was due to the sudden change in the water or not, but it is possible that the conversion of calcium sulphate to sodium sulphate, a mild laxative, may have been conducive to this condition. In any case the adjustments to the new water were soon made, and complaints ceased after a brief time, but in all other plants the softening schedule has not been made so abrupt.

INCREASE IN CORROSIVENESS

Most of these waters have a pH around 7.4 which is not changed by the softening operation. The final product has a hardness of about 4 to 5 grains. Very little complaint has been heard regarding increase in corrosiveness of the water, although there is some evidence that is is slightly more aggressive.

MANGANESE IN MAINS

Some of the distributon systems were heavily coated with manganese, and fear was expressed that the soft water might release or

dissolve this coating. There has been no evidence of redissolving of the manganese, and comparatively little releasing. Usually a schedule of flushing of hydrants has been adopted during the earlier months which has been effective in keeping the manganese from entering consumer's premises. The hydrants ran black streams for some minutes, indicating a loosening of the deposit but this sufficed to keep the manganese well in hand. Later the normal flushing is sufficient. But if neglected, some few houses in a given district may find black flakes in the bath tub. However, this is not more prevalent than prior to softening.

DEMANGANIZATION

Most of the communities installing softeners were not only concerned with obtaining the benefits of softer water, but even in a greater degree desired to free themselves from the obnoxious conditions produced by manganese. It has been found that both iron and manganese are completely removed during the softening cycle, and apparently by exchange action since the curve of removal of manganese follows very closely that for softening. If the softening is stopped with the first appearance of hard water, that is, if only zero water is turned out of the softener, then the outgoing water is free of iron and manganese. In some of the plants the final degree of hardness is obtained by passing through the so-called "twilight" zone, from water of zero hardness to full hardness, and mixing the resulting hard water with the zero water from the other units. The final product, therefore, carries a small amount of manganese. When the manganese content of the raw water is high as at Ambridge (3) (averaging 4.9 p.p.m. and at times reaching 7.2 p.p.m.) it becomes necessary to demanganize the hard water before mixing with the soft water. At this plant this is accomplished by treatment with lime to increase the pH sufficiently so as to throw down most of the manganese in the sedimentation basin and remove it entirely in the quartz sand filter. The water leaving the plant carries only a trace of manganese.

At Edgeworth, experiments were conducted for several months to determine the best and cheapest way of removing manganese, which varied in amount from about 0.6 p.p.m. to 2.0 p.p.m. Water was passed through pyrolusite which, in the beginning, removed about half of the manganese, but as the pyrolusite ore became coated it gradually lost its capacity for taking out manganese. A special

iron removing mineral gave about the same results as pyrolusite when the water was passed downwards, but gave little or no removal when water passed upward through the mineral.

Samples of ordinary green sand were tried from two plants which had been in operation for several years and new samples from several suppliers, as well as specially prepared manganese removing zeolite. In each case the ordinary green sand gave the best results, after the sand had first been heavily treated with an overdose of potassium permanganate, which is used as the regenerating agent. It was also found that calcium hypochlorite could be used for regeneration.

Experiments were made on downward flow and upward flow, and, surprisingly, it was discovered that nearly as good results could be had at an upward flow of 20 gallons per square foot per minute as downwards at a 2 gallon rate.

The plant was designed for an upward rate of 10 gallons per square foot per minute, and has been functioning for nine months without trouble and with no evident loss of sand. The exchange rate for the past six months has averaged 390 grains of manganese removed per cubic foot of zeolite. Monthly averages have varied from 318 to 477 and individual runs have gone as high as 601. The mineral is regenerated when the manganese, passing through, reaches 0.15 to 0.2 p.p.m.

The pounds of potassium permanganate per pound of manganese removed averaged 1.78, but some individual runs have gone as low as 1.10 pounds. These results are exceptionally good. The sand seems to improve gradually with use, since each month (up to July 1937) indicated an improvement in exchange capacity over the previous month.

The process has proved simple and economical in operation and low in first cost since only 66 cubic feet of mineral are required for a 1 M.G.D. rating. During a seven month period preceding August 1937, during which the manganese in the raw water averaged 1.3 p.p.m. and 0.09 in the water leaving the plant, the cost of potassium permanganate in the removal of manganese has been approximately $3.60 per million gallons of water treated through the demanganizers. In June this was down to $2.90. Since the water treated through the demanganizers is only about half of the total leaving the plant, and the remaining manganese is removed while passing through the softeners at practically no extra cost, it may be seen that this procedure has proved quite economical.

The testimony of the years confirms the use of zeolite as a reliable and economical softening and demanganizing medium in situations where the initial raw water is favorable.

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REMOVAL OF DISSOLVED MINERAL SOLIDS FROM WATER BY ORGANIC EXCHANGE FILTERS*

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Like most other raw materials found in nature, natural waters are often unsuitable for many purposes. In most cases water supplies are not water, but are dilute solutions of chemicals, and in addition often bear colloidal matter, suspended particles, and dissolved gases. Because natural water supplies are rarely suitable as found in nature, such waters are processed by one means or another to yield a product which is suitable for the uses to which it is to be put. Those engaged in supplying water for domestic uses must supply a product which is pleasant to taste, which is clear and without odor, and most important of all, free of harmful substances and organisms.

Much water used in industry must meet still further requirements. Some uses demand water which is free of practically all foreign constituents. This last requirement is the most difficult of all to meet. The most common method of producing such water is by evaporation. Another method of producing such water has been described by Bartow (1) and others. This process consists of passing water through an electrolytic cell whereby a product of high quality can be obtained. A new method has been proposed by Adams and Holmes (2). In this process dissolved solids are removed from water by passing it through filters composed of granular organic materials which are best described as "exchangers."

The materials described by Adams and Holmes had a fair capacity but were rather expensive. In order to improve this process other entirely different materials have been developed which have excellent physicial properties, high exchange capacity, and are reasonable in cost. They are essentially organic materials manufactured from readily obtainable industrial products. These exchangers are of

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two types, "acidic" and "basic." The combination of the acidic and basic exchangers with suitable mechanical equipment, comprises a complete unit.

The acidic exchanger is a large aggregate of organic material which contains one or more active hydrogen atoms. When a salt solution, such as sodium chloride, is passed through it, the sodium ions of the salt combine with the large aggregate and release hydrogen ions, which are free to unite with the chloride ions of the salt to form hydrochloric acid.

This same phenomenon takes place when a solution of calcium sulphate is passed through an acidic exchanger, resulting in the removal of the calcium ions from solution, and in the formation of sulphuric acid. Likewise, bicarbonates are converted to carbonic acid.

When this exchanger has been completely saturated with sodium, calcium, and magnesium, it is necessary to regenerate it. This is accomplished by using a dilute acid solution, such as a 1 per cent sulphuric acid solution. When the acid is passed through, sodium, calcium and magnesium appear in the effluent. After washing the unit free of these constituents it is again in condition for the further removal of sodium, calcium and magnesium. During regeneration the hydrogen of the acid replaces the metallic ion which had been previously removed from the water. This is analogous to the action of a zeolite softener. Because this exchanger is regenerated with an acid it is termed an "acidic exchanger."

The acidic water must be further treated to remove the acids. This is done by passing the acidic water through a second unit, which removes the acids to yield a water substantially neutral and free of dissolved solids. This unit is termed a "basic exchanger," as it is regenerated with an alkali. It is a granular organic material which consists of large insoluble molecules having ionizable hydroxyl groups.

It is believed that when an acid, such as hydrochloric acid, is passed through this unit the chloride ion of hydrochloric acid combines with the organic material, and releases the hydroxyl ion which is then free to combine with the hydrogen of the acid to form water. Other acids are removed from water in the same manner. When the basic exchanger has been saturated with chlorides and sulphates it may be regenerated by treating it with an alkaline solution, such as caustic soda. This solution may vary in strength from 0.5 per cent to 5 per cent. During regeneration the hydroxyl ions of the

caustic soda unite with the exhausted bed, releasing chloride and sulphate ions, which react with the sodium of the caustic soda to form salts, such as sodium chloride and sodium sulphate. After washing out these salts and any excess caustic soda, the bed is in condition to remove more acids from solution.

PHYSICAL PROPERTIES

These materials are remarkably resistant to abrasion and chemical attack, except in the action of caustic soda on the acidic exchanger.

These materials are granular solids, which will pass through a 14 mesh sieve and be retained on a 48 mesh sieve, and when dry contain about 15 per cent moisture. Upon being wetted both of these materials swell to approximately one and one-half times the dry volume. After being wetted 30 pounds of dry material will occupy one cubic foot. This figure of 30 pounds is not exact, but is within 10 per cent of the true value to be expected after the materials have become wetted.

These materials have been subjected to shaking tests while being immersed in various solutions. Comparative tests were made on a good grade of synthetic zeolite. In all cases the exchanger materials underwent less mechanical disintegration, and showed much less solubility in neutral and acid solutions than the zeolite. The basic exchanger is very slightly attacked by strong solutions of alkalies, but much less so than a good grade of synthetic zeolite. The acidic exchanger is not affected by the alkalinity of calcium bearing bicarbonate waters, but is attacked by a 3 per cent caustic soda solution. There is no objection to this as in normal usage the acidic exchanger would not come in contact with alkaline solutions of strengths sufficient to cause disintegration.

The excellent physical and chemical properties of these materials are quite surprising in view of the fact that they are not as hard as zeolites in the wetted condition. The good physical properties are attributed to the fact that they may undergo slight deformation without breaking. This would suggest the possibility that packing would take place in these beds; however, such is not the case.

CAPACITY

These exchangers have different capacities for the various ions found in water. For instance, calcium is removed in preference to magnesium, and magnesium is removed in preference to sodium.

However, the calcium and magnesium are very close together. The capacity for these ions is greater in bicarbonate or alkaline solutions than in neutral solutions.

In calculating the capacity of the acidic exchanger for any given water, it is necessary to consider the alkalinity, the amount of sodium, and the amount of hardness. The negative ions present also affect the capacity for sodium and hardness. Chlorides and sulphates have about the same effect, but the presence of bicarbonates increases the capacity for sodium and hardness.

TABLE 1

Capacity of a typical acidic exchanger

SALTS	GRAINS PER CUBIC FOOT
Sodium Chloride	5,800
Sodium Sulphate	6,600
Sodium Bicarbonate	10,900
Magnesium Sulphate	6,800
Calcium Sulphate	7,500
Calcium Bicarbonate	13,600

TABLE 2

Capacity of a typical basic exchanger

ACIDS	GRAINS PER CUBIC FOOT
Carbonic Acid (H_2CO_3)	1,000
Hydrochloric Acid (HCl)	2,400
Sulphuric Acid (H_2SO_4)	25,000

The basic exchanger has a higher capacity for sulphuric acid than for hydrochloric acid, and a higher capacity for hydrochloric acid than for carbonic acid.

The method of manufacture will influence the capacity of these exchangers for the various ions. For example, the capacity for chloride ions can be increased with a corresponding decrease in capacity for sulphates. This makes it possible to adjust the exchanger to the type of water to be treated, depending upon the amount of chlorides and sulphates to be removed.

When the basic exchanger has become saturated with carbonic acid, stronger acids will replace it. In like manner when it has

become saturated with hydrochloric acid in the presence of sulphuric acid, further additions of these acids will result in the displacement of hydrochloric acid, with sulphuric acid being removed from the water at the expense of hydrochloric acid.

EQUIPMENT

Most of the equipment required must be resistant to the action of dilute sulphuric, hydrochloric and carbonic acids, and in addition part of the equipment must be resistant to the action of dilute caustic soda solutions. Rubber lined tanks, valves and fittings meet these requirements, but are rather expensive. Wood tanks also meet these requirements, but in case wood is used it is necessary to use open tanks, and depend upon gravity to filter the water through the unit. It is also necessary to pump water from the first unit to the second, and then to storage, unless the units are mounted in such a manner as to allow gravity flow. It is necessary to use an acid resistant container for the second unit as the water coming in at the top is acidic, and as the basic exchanger becomes exhausted the acidic water will penetrate further towards the bottom of the basic exchanger.

To avoid the use of pumps for proportioning, both the acid and caustic soda required for regeneration can be introduced to the units by ejectors.

CONTROL

Chemical control is necessary during regeneration to determine the point at which the units become exhausted.

After the acidic exchanger has been regenerated with an acid, the salts formed during the regeneration, and any excess acid which may have been used, are washed out with untreated water. Titrations of the effluent during the washing period show that the acidity rapidly decreases until it reaches a constant value. This value is known as the "normal operating acidity." The normal operating acidity varies with different waters. The dissolved solids are converted to acids, and as carbon dioxide does not influence the methyl orange indicator, the acidic titration at the normal operating value is equal to the sum of the chlorides, sulphates, nitrates and phosphates, if any, in the water being treated. Thus after regeneration, when the acidity falls to this normal operating acidity, further effluent is directed to the second unit.

To determine the point at which the first unit is becoming exhausted a simple titration of the effluent will show whether or not the acidity has fallen below the normal operating acidity, and if so, it should be regenerated.

The operation of the second unit is somewhat similar. It is regenerated with caustic soda. After the caustic soda has been added, the salts formed during the regeneration, and the excess caustic, if any, are washed out. Simple tests using phenolphthalein as an indicator on the effluent will indicate when there is no more alkalinity coming from the unit. A secondary test for chlorides using silver nitrate, when chlorides are present in the raw water, will determine whether or not the water is free of dissolved solids. One or both tests may be used.

The exhaustion point of the basic exchanger is indicated when the chloride determination of the effluent is greater than the desired value, which in most cases is about one-half to one grain per gallon. As an alternate method of determining the exhaustion of this unit titrations of the acidity passing through may be made.

Mechanical operation involves the opening and closing of valves which are arranged in about the same manner as those of a filter.

COST

The chemical operating costs depend upon the amount and type of dissolved solids in the water. If the water to be treated contains bicarbonates only it is quite obvious that a second exchanger is not necessary as the first converts all of the bicarbonates to carbonic acid, which may be removed by aeration to leave the water substantially free of dissolved solids.

Waters which contain chlorides and sulphates, as well as bicarbonates can be treated with the acidic exchanger so as to secure a reduction in dissolved solids equivalent to the bicarbonates. In this case the methyl orange acidity in the water may be neutralized with an alkaline solution, and the mixture aerated to yield a product containing only chlorides and sulphates. For example, when reduction of the dissolved solids equivalent to the carbonates or bicarbonates only is desired the cost of acid for regenerating would be 0.32 cents per 1000 grains of calcium carbonate equivalent removed. For a water containing 10 grains per gallon of bicarbonates as calcium carbonate the cost of acid would be 3.2 cents per 1000 gallons. However, there would be no reduction in the concentration of sulphates

or chlorides. Similar results can be obtained by well known chemical means, usually at less cost, except with water containing large amounts of sodium bicarbonate.

The process of using the acidic exchanger alone is not satisfactory when sulphates and chlorides are present in objectionable amounts, and in order to remove them a basic exchanger must be used. The cost of operating both beds will increase the cost of treating water, but where removal of sulphates and chlorides is desired, the increased cost is moderate and is low compared to other means of accomplishing this.

Lake Michigan water containing 10 to 11 grains per gallon of dissolved solids can be treated with both units for 6.5 cents per 1000 gallons. A well water near Chicago bearing 29.4 grains per gallon of dissolved solids (of which 7.4 grains per gallon are due to bicarbonates) can be treated for 30.2 cents per 1000 gallons. As another example;—a surface water containing 36.8 grains per gallon of dissolved solids, including 12.6 grains per gallon of sodium sulphate, can be treated so as to reduce the dissolved solids to 1.5 grains per gallon at a cost of 35 cents per 1000 gallons. These costs are based on chemicals bought in small lots, and would be greatly reduced if based on carload purchases.

The amount of sulphuric acid required for regenerating depends upon the amount of sodium, calcium and magnesium which it is desired to remove from the water. Likewise, the amount of caustic soda required depends upon the amount of chlorides, sulphates, nitrates and other non-volatile acids which must be removed. It is not neccessary to take into account caustic soda for the removal of carbonic acid, since the capacity for carbonic acid is low, and a large part of the carbonic acid is passed through the system so that the effluent delivered by the basic exchanger contains CO_2, which is removed by aeration.

The entire process, therefore, consists of removing ionized dissolved solids from water by passing the water containing these solids through a bed in which the salts are converted to acids, and then passing the acidic water through a second bed in which the acids are removed from solution to yield a water substantially neutral and free of dissolved solids.

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COAGULATION AS APPLIED TO INDUSTRIAL WATERS*

By A. P. Black,[1] R. A. Bardwell,[2] and B. W. Graham[3]

Methods for improving the quality of industrial water supplies by the process of coagulation are not essentially different from those employed for the treatment of municipal supplies, but the criteria which are used to evaluate the results obtained are not always the same. In the case of municipal supplies, color and turbidity, when present, must be either completely removed or reduced to very low values. This is also true of water to be used for most industrial purposes. Likewise, the removal of tastes and odors and the preparation of a water of high bacteriological quality is equally important to the domestic consumer and to many industries. With respect to hardness and salinity, however, the requirements may be quite different. There are some industries which can and do make use of waters of much greater hardness and salinity than would be tolerated by the average community, but there are many others that require waters softened to zero hardness or to a degree which may not be economically justified for domestic use. In softening municipal water supplies free from color and turbidity by the lime-soda process, the coagulant is employed solely to bring about better settling, and the further reduction of the residual hardness is not a factor. On the other hand, when softening waters to be used for steam raising purposes, the use of a coagulant which can effect a greater reduction in residual hardness than that theoretically obtainable without it possesses obvious advantages. The same situation exists with respect to the removal of silica. It has been repeatedly shown that the coagulation of waters with alum or ferric compounds has little or no effect in reducing the silica content of the water. This fact is of no significance to the domestic consumer

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but its importance in the preparation of boiler feedwater cannot be overemphasized. The ideal coagulant for use with boiler feedwater would be one capable of assisting materially in the softening reactions and lowering the residual hardness, of effecting the complete removal of silica, and which would produce these desirable results economically and without unduly increasing either the causticity, the acidity or the salinity of the treated water. We are all well aware of the fact that the search for this ideal coagulant has thus far proved unsuccessful, although much progress has been made.

This paper will attempt to review a few of the most important aspects of the coagulation of industrial water supplies, with particular emphasis upon the external treatment of boiler feedwater.

ALUM AND FERRIC SALTS AS COAGULANTS

Alum is still without doubt the most widely used coagulant when all types of waters are considered, but a definite trend toward the increasing use of ferric compounds may be noted. Alum, of course, possesses the advantages of lower cost, ease of handling and stability.

The statement that alum is lower in cost than ferric compounds is open to question in many instances where comparison is made on the basis of equivalent effective oxide content. The choice of a coagulant to be used, other things being equal, should always take this into consideration. The ferric compounds now available commercially are; ferric sulfate, ferric chloride (in the form of the anhydrous salt, the hydrated salt or a concentrated solution) and chlorinated copperas. These vary widely in total iron content from approximately 34 percent in the case of the anhydrous ferric chloride to about 15 percent in the case of commercial 45 percent ferric chloride solution. Chlorinated copperas is, of course, prepared as needed by oxidizing copperas solution with chlorine in the ratio of about 1 pound chlorine to 7.8 pounds of copperas. In practice it has been found advisable in many cases to use chlorine in excess of that theoretically required.

Several advantages have been claimed for the ferric compounds. Most important, perhaps, is the fact that the ferric floc is quite insoluble over the entire pH range above pH 3.5 whereas the zone of minimum solubility of alum floc falls within the much narrower range of pH 5 to 9. Baylis (1) presents some evidence that by the addition of specially prepared silicate solution, copperas itself may be made to form satisfactory flocs without the addition of lime, but the data are too incomplete at present to draw definite conclusions.

Other advantages claimed for ferric coagulants are a quicker forming and quicker setting floc (due to higher density), removal of hydrogen sulfide and removal of manganese at pH values above 9. In waters of very low sulfate content, it has been claimed that ferric chloride, chlorinated copperas and ferric sulfate are increasingly effective in the order named, due to the coagulating effect of the sulfate ion added with the coagulant.

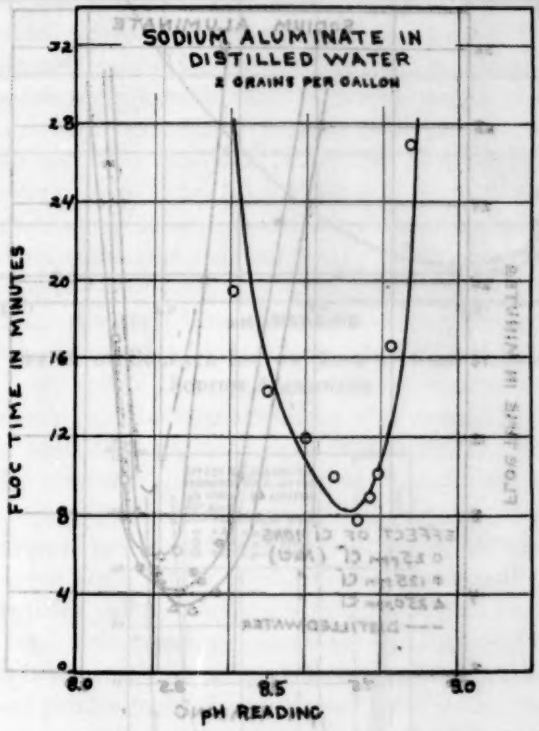

FIG. 1. pH ZONE OF FLOC FORMATION OF SODIUM ALUMINATE IN DISTILLED WATER

SODIUM ALUMINATE

Sodium aluminate is available in solid form or in concentrated aqueous solution containing some excess caustic alkali. Its use as a coagulant marks a distinct step forward in the treatment of boiler feedwaters, since it not only enhances coagulation, but reduces the residual hardness further than is possible by straight lime-soda softening and also reduces silica to a varying degree. These effects

will be discussed separately, and only external treatment will be considered.

Floc Formation with Sodium Aluminate: Sodium aluminate flocs well in distilled water and when used in conjunction with lime-soda softening greatly increases the size of the floc particles and decreases the time required for settling. As in the case with alum and ferric salts, the pH zone of coagulation in distilled water and in soft waters

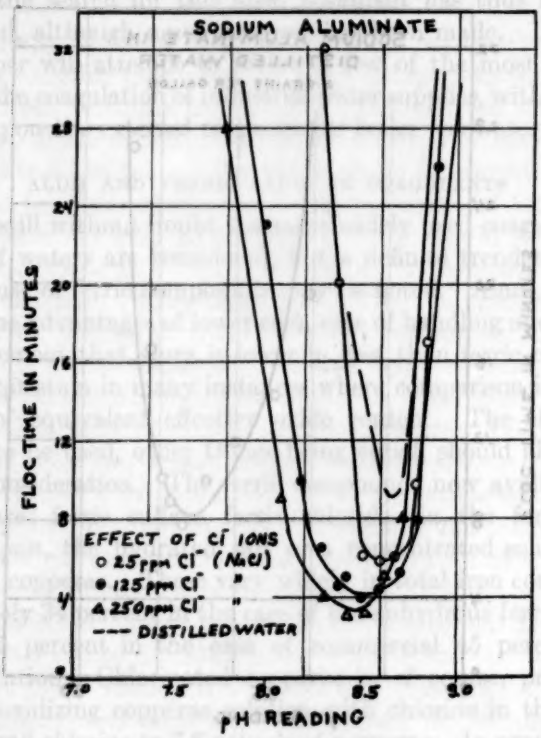

FIG. 2. EFFECT OF CHLORIDE ION ON ZONE OF FLOC FORMATION OF SODIUM ALUMINATE

of low mineral content is relatively narrow. This is shown in figure 1. The dosage is 2 grains per gallon of sodium aluminate. Figure 2 indicates that concentrations of chloride ion varying from 25–250 parts per million and added as sodium chloride have little effect. Figure 3 shows the effect of 25 and 125 parts per million of sulfate ion added as sodium sulfate. It is seen that the zone of rapid floc formation extends well down into the acid range. Figure 4 shows

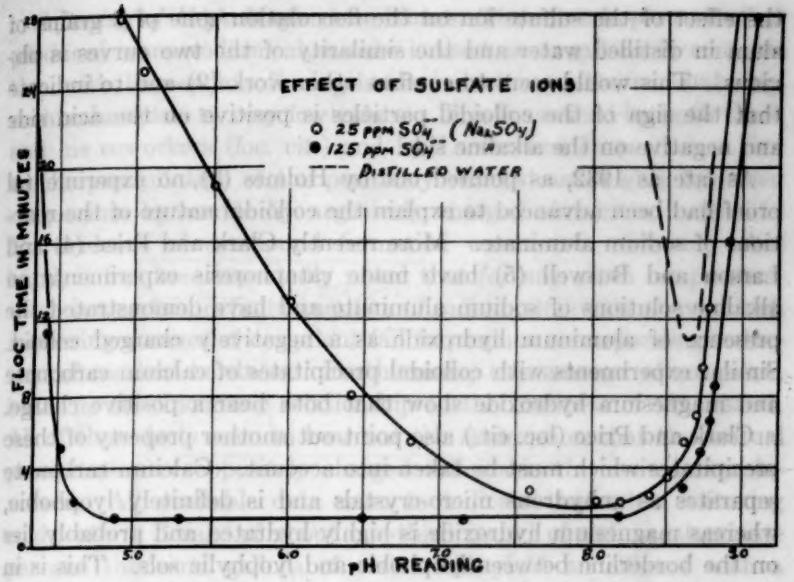

FIG. 3. EFFECT OF SULFATE ION ON ZONE OF FLOC FORMATION OF SODIUM ALUMINATE

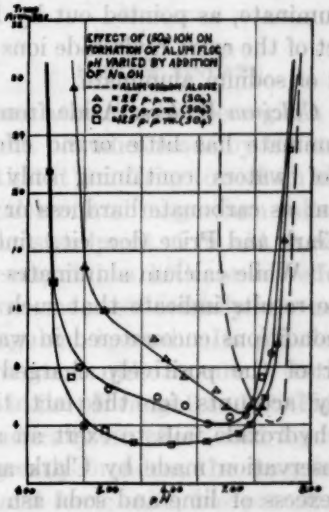

FIG. 4. EFFECT OF SULFATE ION ON ZONE OF FLOC FORMATION OF ALUMINUM SULFATE

the effect of the sulfate ion on the flocculation zone of 2 grains of alum in distilled water and the similarity of the two curves is obvious. This would seem to confirm other work (2) and to indicate that the sign of the colloidal particles is positive on the acid side and negative on the alkaline side.

As late as 1932, as pointed out by Holmes (3), no experimental proof had been advanced to explain the colloidal nature of the reactions of sodium aluminate. More recently Clark and Price (4) and Larson and Buswell (5) have made cataphoresis experiments on alkaline solutions of sodium aluminate and have demonstrated the presence of aluminum hydroxide as a negatively charged colloid. Similar experiments with colloidal precipitates of calcium carbonate and magnesium hydroxide show that both bear a positive charge.

Clark and Price (loc. cit.) also point out another property of these precipitates which must be taken into account. Calcium carbonate separates as anhydrous micro-crystals and is definitely lyophobic, whereas magnesium hydroxide is highly hydrated and probably lies on the borderline between lyophobic and lyophylic sols. This is in accordance with the behavior of magnesium hydroxide flocs when a coagulant is not present.

Still a third point which must be considered in connection with the action of sodium aluminate, as pointed out by Larson and Buswell (loc. cit.) is the effect of the extra hydroxide ions formed by hydrolysis of the molecules of sodium aluminate.

Softening of High Calcium Waters: Aside from improved floc formation, sodium aluminate has little or no effect in reducing the residual hardness of waters containing only calcium hardness, whether it be present as carbonate hardness or as incrustant hardness or both, and Clark and Price (loc. cit.) find no alumina in the precipitates formed. While calcium aluminates have been prepared and described, these results indicate that such compounds are not formed under the conditions encountered in water softening. The lyophobic character of the positively charged calcium carbonate precipitate probably accounts for the fact that the negatively charged aluminum hydroxide fails to exert an appreciable effect.

An interesting observation made by Clark and Hamer (6) is to the effect than an excess of lime and soda ash will yield waters of lower residual hardness than will an equivalent excess of sodium hydroxide. The assumption is advanced that the nuclei of calcium carbonate provided in the first case promote more complete separation of the solid phase.

Softening of High Magnesium Waters: The most important effect produced when sodium aluminate is used as coagulant in conjunction with lime-soda softening is the reduction of the residual magnesium hardness to very low values. This is ascribed by both Clark and his coworkers (loc. cit.) and by Larson and Buswell (loc. cit.) to the precipitation of the positively charged and highly hydrated magnesium hydroxide by negatively charged aluminum hydroxide. No evidence of compound formation was noted. On the other hand, it has been repeatedly noted that for any given temperature there is a certain definite quantity of sodium aluminate above which increasing dosages of coagulant fail to produce corresponding reduction of residual hardness. Furthermore, this amount of coagulant bears no stoichiometric relationship to the hardness of the waters. All of these facts seem to bear out the assumption that the mutual precipitation of oppositely charged colloids is the main factor involved. All available data seem to indicate that when softening cold water a dosage of about one-third pound of sodium aluminate per one thousand gallons of water will yield an effluent with a residual hardness in the neighborhood of 22 p.p.m. and that when the water is softened at a temperature of 60°C. or above the residual hardness may be reduced to around 10 p.p.m. with somewhat less coagulant.

SODIUM ZINCATE

In recent years some attention has been given to the use of sodium zincate as a coagulant. Studies made by the authors (7, 8) and by others (9) indicate that it is inferior to sodium aluminate. The flocs formed with both calcium and magnesium salts are large and settle readily, and from the standpoint of its aid to coagulation it is quite satisfactory. However, it has little or no effect in reducing the residual hardness, in some cases actually increasing it over that obtained when no coagulant is used. Its pH flocculation zone, like that of sodium aluminate, is quite narrow in distilled water, as shown in figure 5, and falls in the pH range 9 to 10. Figure 6 shows that the chloride ion has practically no effect, and figure 7 shows that the sulfate ion, which greatly broadens the coagulation zones of alum, sodium aluminate, and ferric salts, has practically no effect in the case of sodium zincate. On the other hand, both the calcium ion (see figure 8) and the magnesium ion (see figure 9) greatly speed up floc formation and broaden the pH zone. The effect is particularly noticeable in the case of the magnesium ion. Below pH 10.5 the

floc cannot be due to magnesium hydroxide, since calculations indicate that for the concentrations of magnesium ion employed, the hydroxide will not precipitate below this pH value.

These curves would seem to indicate that the colloidal zinc hydroxide bears a negative charge. Britton (10) when titrating zinc salts with sodium hydroxide solution, reported that zinc hydroxide adsorbs hydroxyl ions to form a negative colloid, a conclusion con-

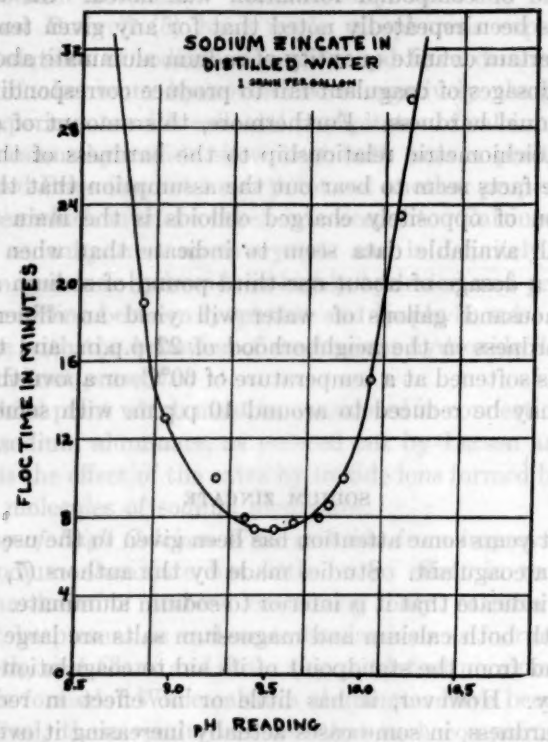

FIG. 5. pH ZONE OF FLOC FORMATION OF SODIUM ZINCATE IN DISTILLED WATER

firmed by Mohanlal and Dhar (11). Ghosh and Dhar (12) have measured the coagulating power of alkali cations on colloidal zinc hydroxide, thus indicating its negative character. If this be true, it is difficult to understand why the negatively charged zinc hydroxide does not act like the negatively charged aluminum hydroxide in precipitating the positive magnesium hydroxide. This point would seem to need further investigation.

SILICA REMOVAL

The primary consideration in the external treatment of boiler feedwaters is, of course, the maximum removal of all scale-forming ingredients. Operating experiences and the chemical analysis of various types of boiler scales emphasize the fact that in some cases the removal of silica may be even more important than the removal of calcium and magnesium. From one to five parts per million of

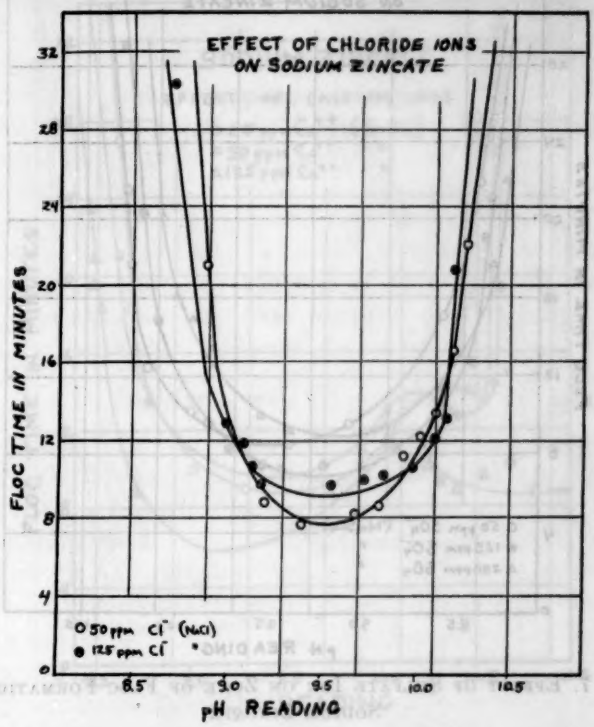

FIG. 6. EFFECT OF CHLORIDE ION ON ZONE OF FLOC FORMATION OF SODIUM ZINCATE

silica is often present in what may be considered properly conditioned feedwaters and occasionally adherent rope scale deposits of calcium silicate are formed in boiler tubes due to the presence of this silica. This is especially true at the higher pressures. Also, when high evaporation rates are used, and boilers remain in service for extended periods, these silica concentrations build up greatly (13). There are, of course, several possible sources of this silica among which

may be mentioned condenser leakage, carryover from evaporators, inherent silica due to its solubility in alkaline feedwater, small amounts in conditioning chemicals, and that dissolved from siliceous filtering media after conditioning and settling. While internal treatment with phsophates, aluminates, or other compounds may

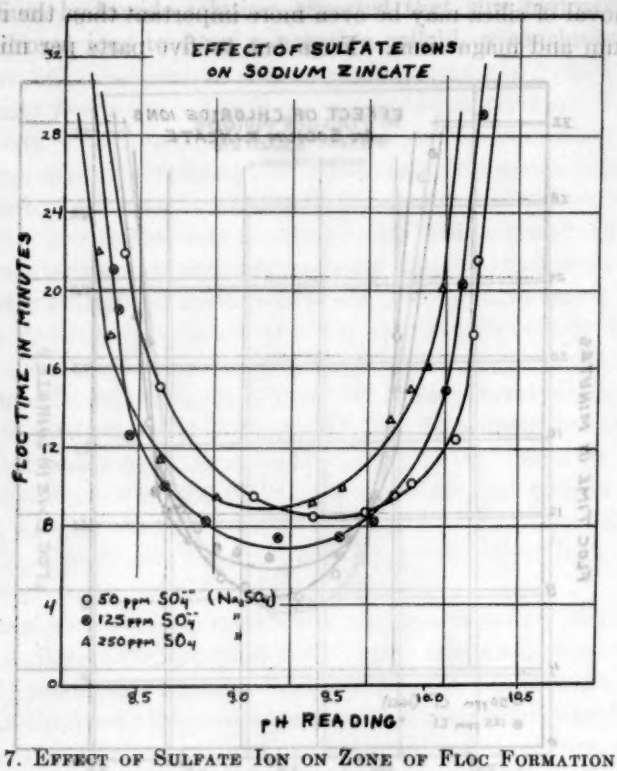

FIG. 7. EFFECT OF SULFATE ION ON ZONE OF FLOC FORMATION OF SODIUM ZINCATE

prevent the formation of adherent scale, it would seem highly desirable to remove even these small traces of silica in the external treatment.

Lime-soda softening in itself has some effect in the removal of silica from boiler feedwaters. This is especially noticeable when the silica content is high and when the water contains considerable magnesium hardness. Excess caustic alkalinity causes the removal to be less complete and little or no effect is noted when only small amounts of silica are present.

Christman, Holmes and Thompson (14) have found that when sodium aluminate is added to hard waters containing silica, much of the silica is precipitated as complex calcium and magnesium aluminosilicates, the removal being more complete at high temperatures. The presence of excess alkali retards the precipitation and increases the silica content of the treated water. When large amounts of silica are present, a high percentage reduction is easily

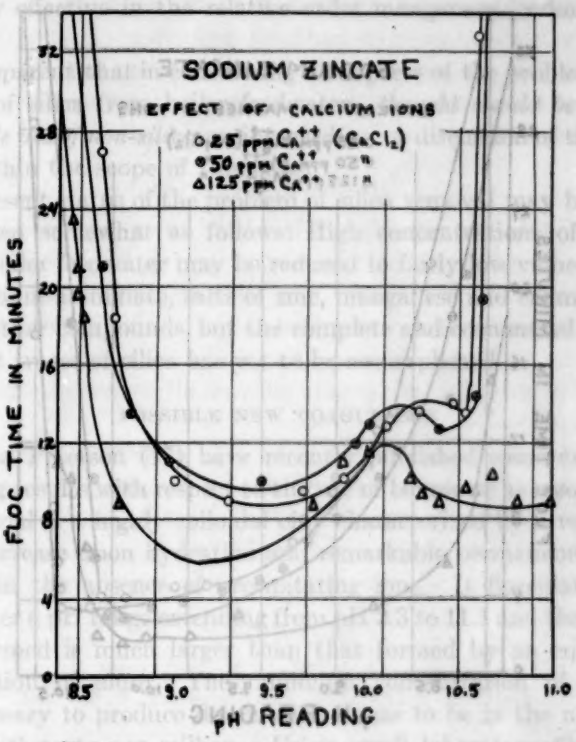

FIG. 8. EFFECT OF CALCIUM ION ON ZONE OF FLOC FORMATION OF SODIUM ZINCATE

obtained. For example, treatment of a water containing 85 parts per million of silica with lime and 1 grain of sodium aluminate effected 59 per cent reduction in the silica and 5 grains of aluminate gave an effluent containing only 7 parts per million of silica, a reduction of over 90 percent. When magnesium salts are used instead of lime, removal is even more complete, the magnesium aluminosilicate appearing to be more insoluble than the corresponding calcium compound.

The dried precipitates were shown to be of a zeolite nature, having considerable exchange capacity. In hot process softening and with moderate concentrations of silica one-seventh pound of sodium aluminate per thousand gallons of water removed about 70 per cent of the silica and trebling the dose had little additional effect. Furthermore, for this particular water, softening without the use of sodium aluminate gave about 60 percent removal. The authors

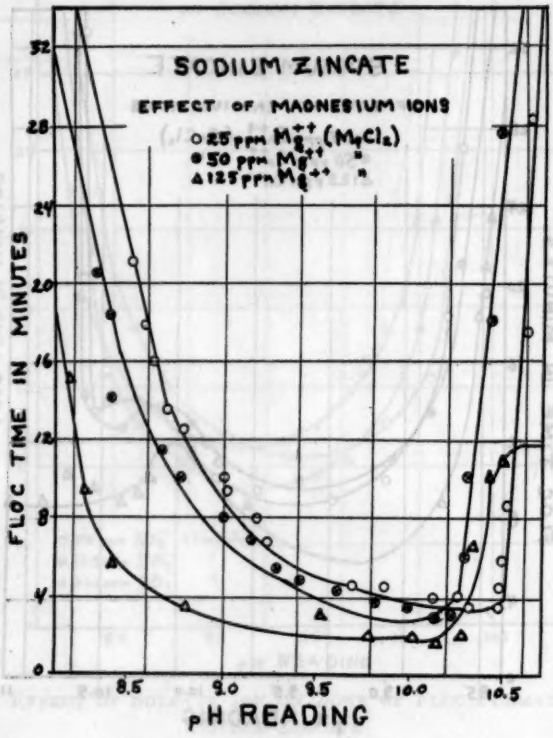

FIG. 9. EFFECT OF MAGNESIUM ION ON ZONE OF FLOC FORMATION OF SODIUM ZINCATE

recommend the use of sufficient sodium aluminate to give good coagulation and maximum silica removal and to provide sufficient soluble alumina in the treated water to precipitate the remaining silica as a non-adherent alumina silicate sludge in the boiler.

Reimers (16) has patented a method for the removal of soluble silica from water which consists, in effect, of the addition of soluble salts of cadmium, manganese and zinc together with sodium hydrox-

ide. When relatively large amounts of soluble silica are present, it is claimed that the addition of the stoichiometric quantity of any of these salts will reduce the residual silica to 1 to 5 parts per million. On the other hand, it is stated in the patent that in case of waters of relatively low silica content, as much as fifteen times the calculated quantity of these salts must be added to reduce the concentration of silica to the above values. It is claimed that the salts are increasingly effective in the relative order manganese, cadmium and zinc.

It is apparent that in considering all aspects of the problem of the removal of silica from boiler feedwaters, *thought should be given to the possible use of non-siliceous filter media.* A discussion of this point is not within the scope of this paper.

The present status of the problem of silica removal may be briefly summarized somewhat as follows: High concentrations of soluble silica in boiler feedwater may be reduced to fairly low values by the use of sodium aluminate, salts of zinc, manganese and cadmium and possibly other compounds, but the complete and economical removal of the last traces of silica has yet to be accomplished.

POSSIBLE NEW COAGULANTS

Olin and Peterson (17) have recently published some extremely interesting results with respect to the use of bentonite as a coagulant. The material is a highly colloidal clay characterized by a very large volume increase upon hydration and remarkable permanence in the sol state in the absence of precipitating ions. It flocculates very rapidly over a pH range extending from pH 2.3 to 11.1 and the volume of floc formed is much larger than that formed by an equivalent concentration of alum. The minimum concentration of mineral salts necessary to produce flocculation seems to be in the neighborhood of 100 parts per million. Using small laboratory filters the filtration rate of waters coagulated with bentonite is found to be slightly more rapid and the loss of head less than for waters coagulated with alum. The material also possesses a slight exchange capacity. A consideration which might make the material useful for the coagulation of boiler feedwater is its property of forming exceedingly rapid and very bulky flocs at high pH values such as are encountered in overtreated waters. It is unlikely that it would prove suitable where silica removal is a major factor.

Titanium Salts as Coagulants: Upton and Buswell (18) have re-

cently presented interesting data with respect to the use of titanium sulfate as a coagulant. The salt was used alone and in combination with ferric sulfate. At low temperatures the titanium salt was found to form flocs more rapidly than the same amount of alum. Advantages claimed for the new coagulant are that it forms bulkier flocs very rapidly, coagulates over a wider pH range, coagulates better in high dissolved salt concentrations, and gives better flocculation at low temperatures than either alum or ferric sulfate. No data are given with respect to hardness reduction or silica reduction. While the data are interesting, it does not appear that the compound offers any advantages over coagulants at present available as far as boiler feedwaters are concerned.

PROBLEMS WHICH AWAIT SOLUTION

Many problems still await solution in order to secure all the advantages which might be expected to accrue from the coagulation of industrial water supplies. The authors, in concluding this brief and incomplete summary, venture to suggest four which might well engage the attention of those interested in this field:

1. The complete removal of silica at all concentrations met with in practice.
2. The effect of catalysts to be used with present coagulants in promoting better or more economical coagulation.
3. Possible new coagulants.
4. Possible compound formation when sodium aluminate is used in conjunction with lime-soda softening.

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THE DIVERSIFIED ACTIVITIES OF OUR WATER SALES DIVISION

By Thad M. Erwin

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(Department of Water and Power, Los Angeles, Cal.)

Before entering into the real subject of our discussion, I would like to give a brief resume of the history of our water supply.

Los Angeles has been described as a city situated in a semi-arid desert country, blessed with an ideal climate and wonderfully fertile valleys, but with an insufficient supply of natural rainfall. Our city's first water system was entirely dependent upon this rainfall but it answered the purpose for the sleepy little Spanish pueblo. It consisted of an irrigation canal, built through community effort, from the Los Angeles River to a point near our old Plaza, and the Indians delivered this water by barrel and wheelbarrow—later on constructing a dam across the river and carrying water to the inhabitants by a system of ditches; and this river was the only water supply at the time the City of Los Angeles purchased the water system in 1902. The population was 160,000 by this time and increasing so rapidly that it was soon realized that this river, even under normal conditions, was not capable of supplying more than 250,000 people. If the city was to continue to grow, they must provide for this growth by finding an additional adequate and dependable water supply.

After much study and a personal survey of all possible sources, Mr. William Mulholland, then Chief Engineer of the Municipal Water Bureau, located such a supply far to the north of Los Angeles—where the Owens River, fed by the pure sparkling snow waters of the High Sierras, poured into Owens Lake. He was convinced that bringing this water to Los Angeles was both practical and necessary. The citizens had such faith in his judgment that they voted bonds to cover the $24,500,000 estimate of cost of bringing this water to Los Angeles—a five year task. Bringing water

* Presented at the Buffalo convention, June 8, 1937.

this great distance has been likened to St. Louis bringing water from Lake Michigan. But in 1913, the 238 mile aqueduct, greatest in the world, winding its way across deserts, tunneling mountain ranges, diving across canyons in giant siphons, was completed; and Los Angeles entered upon an era of prosperity and growth never before equaled. There was water for everyone; and the surplus waters were used to convert desert areas into blooming orange groves, fruit orchards and prosperous ranches—building up the back country so necessary to a thriving city.

When this Owens Valley water was brought to our mains 25 years ago, it was felt that our water supply problems were solved for all time—but such was not the case. Today, in order to augment this aqueduct supply, we are reaching one hundred miles beyond the Owens Valley to the Mono Basin country; and when our construction program there is completed, the flow from five more mountain streams will be added to our Owens River supply, thus increasing this supply by approximately 30 per cent. Additional demands, from both Los Angeles and the surrounding territory, will in the very near future, be met by a supply from the Colorado River, where the flow is now controlled by the Boulder Dam; and Los Angeles and her sister cities, through an organization known as the Metropolitan Water District, have joined in building an aqueduct that will bring this additional supply to our city.

It can readily be seen that the distribution of this vast water supply is not a simple matter; for we have the second largest water distribution system in the United States. To cover the 450 square miles of our city we have installed approximately 4000 miles of mains, varying from 4 to 78 inches in diameter. Sixty-two reservoirs and tanks in the system are capable of storing 57 billions of gallons of water, and of this amount 17 billion gallons is stored within the city limits.

The Water Sales Division plays a very active part in the selling of this water, as all orders for new water services, street main extensions, and related work, are handled by this office with the assistance of seventeen branch offices distributed over the city for the convenience of the public. I will try to give you a comprehensive idea of the various activities and responsibilities in connection with the sale of this water.

WATER SERVICE SALES

All applications for new water service connections together with all monies collected, are received from these seventeen branch offices and cleared through the Water Sales Division, where the original installation orders are written up and delivered to the Meter and Service Division. As a matter of information, our records show that we have more than 266,000 metered services at the present time. Now that business of all descriptions is on a definite upward trend, approximately 500 new water services are being installed in Los Angeles each month.

In addition to our regular Domestic service, we have our Commercial, Industrial, Temporary, Fire, Combination Irrigation and Domestic, and Intermittent Irrigation services.

The price for all water services up to and including two-inch are flat rates, established in our Rules and Regulations and approved by the Board of Water and Power Commissioners. All sizes in excess of 2-inch are installed at actual cost.

All applications for service of any character in excess of size 2-inch require a special inspection and investigation, and the applicant is then notified of the approximate cost and required to make a deposit of half the cost or furnish sufficient bond to cover the actual cost of the installation. Upon completion of the work, applicant is billed with the balance due or total cost.

Under a law known as the 1911 Street Improvement Act, the City Engineer has the authority to order all underground improvements to be made in advance of street paving. This act requires our department to install water connections to each lot, same to be paid for by the property owners through a bond issue.

Temporary services are installed for the benefit of contractors, moving picture sets, oil wells, circuses and rodeos—where there is no regular service available. These temporary services are installed for short periods only, never exceeding six months.

Any change of water service from small size to a larger size is treated as a new service.

When meter location is changed for the benefit of a consumer, the consumer pays material and labor costs involved.

STREET MAIN EXTENSIONS

All applications for extensions from our existing water lines may be classified as follows: New subdivisions, industrial tracts and private individuals.

New Subdivisions (Residential). At the request of the subdivider of residential property, estimate is furnished on the cost of installing a complete water system, consisting of mains, service connections and fire hydrants, to serve the entire tract.

This cost covers piping of streets at $1.60 per lineal foot (no refund allowed) plus $100.00 each for fire hydrants, and the regular service connection charge, according to the size of service desired. No mains are installed where streets have not been dedicated to public use. Fire hydrants are installed at each intersection, or, ordinarily every six hundred feet.

Where abutting property is *not* the property of the subdivider, he pays a deposit of 80 cents per front foot and the full amount of the deposit is refunded to the payor or his assigns as the frontage tax is collected when application for new connection is received.

Before a final estimate on such a subdivision is submitted, the subdivider must fill in our "Questionnaire" form, stating that streets are down to sub-grade and that the tract is of final record and approved by the City Planning Commission. When this office receives the signed questionnaire and check to cover the cost of requested installation, a Street Main Extension Order is issued covering this work.

These extension orders cover any work to be performed by our Distribution Operation Division and each order is assigned a number and written up in the Water Sales Division on regular forms, consecutively numbered. Main District, San Fernando Valley District and Harbor District are each assigned a special set of serial numbers in order that numbers will not conflict when final reports are made. Extension orders, instructing field men to proceed with these installations, are made out in quintuplicate in order that all divisions having a working interest may receive a copy for their information and records.

Industrial Tracts. Estimates are prepared for the installation of water supply systems for industrial districts, but billing is handled on a basis of labor and material cost plus engineering supervision expense; for, as a rule these installations require size 8-inch and larger pipe in order to obtain a water supply that will be adequate at all times.

Private Individuals. Extensions of water mains are made for private individuals on a basis of 200 feet for each active consumer, providing applicant pays street main assessment charge of 80 cents

per front foot for the property to be served, plus the regular service connection charge—which varies with the size of service required.

All intervening property is then marked on our district sheets or maps with a special symbol denoting that the street main assessment frontage charge of 80 cents per front foot is due; and this assessment must be collected before an application for service there can be accepted.

Elevation agreements. In our city (covering 450 square miles) the task of selling water is complicated by the variety of elevations at which water must be served. The extremes are from sea level to an elevation of 1720 feet. In some instances, it is necessary to lift water 570 feet. Fourteen billion gallons of pumped water are served yearly.

Where the property to be served is less than 100 feet lower than the reservoir from which the supply will be received, the owner of the property is required to sign an agreement to accept such service as can be supplied from our existing distributing system, and absolving the department from responsibility for any additional supply. This agreement is then legally recorded.

WATER RATES

The Water Sales Division is also responsible for the preparation as well as the revision of our water rate ordinances, which are rewritten every two years, and the formulation of any desired changes by amendment to such ordinances, during the two years. These two water rate ordinances, governing the sale of water both inside and outside the city limits, are first presented to our Board of Water and Power Commissioners (consisting of five members) for their adoption, and afterward transmitted to the City Council of the City of Los Angeles for approval.

Domestic, Commercial and Industrial Rates. Despite the area and elevations served and the distance the water must be brought before entering our distribution system, the rates are very low—thirteen cents per hundred cubic feet for domestic, industrial and commercial consumption—five cents lower than the average rate of 183 largest United States cities. This thirteen cent rate governs for the first 10,000 cubic feet; the next 40,000 cubic feet is eleven cents; the next 50,000 cubic feet is nine cents; and all in excess of 100,000 cubic feet is billed at seven cents per hundred cubic feet.

Combination Irrigation and Domestic Rate. We have a combi-

nation domestic and irrigation service for consumers who have a half acre or more of ground planted to fruits, alfalfa or vegetables raised for commercial purposes; and this rate also applies to small chicken ranches. Their minimum bill varies with the size of the service connection; for example, a one-inch service carries a minimum charge of $1.65 for 1300 cubic feet, which is our regular rate of thirteen cents per hundred cubic feet. But, all water used in excess of the 1300 cubic feet, is billed at four cents per hundred cubic feet, if from gravity system—and six cents per hundred cubic feet for water used from pumped system. During the past year the Water Sales Division has been responsible for the approval or disapproval of approximately 5300 such applications for combination irrigation and domestic service, in all districts.

Intermittent Irrigation. We also have an intermittent irrigation rate used on larger parcels of land where planted to agricultural, floricultural and horticultural crops. This water is supplied intermittently and solely for irrigation for limited periods. The rates are 1.5 cents per hundred cubic feet for all water supplied by gravity water system and 3.5 cents per hundred cubic feet for all water supplied by pumped system—with a minimum charge of $2.00 for each time the water is turned on.

Special Rates. Other city departments, such as parks and playgrounds, our library buildings and governmental agencies, golf clubs and polo fields, have a special rate of five cents per hundred cubic feet.

Automatic sprinkler service and fire services, and water used for construction purposes, sewer flushing and street sprinkling all have special rates.

County Rates. Water is served to consumers in the county where property is contiguous to the city and mains already exist—or where trunk lines feeding other parts of the city cross county territory, or where we have acquired lines. Under any of these conditions, property bordering on these lines can secure service by paying the 80 cents per front foot street main assessment charges, plus the regular service connection charge, and the regular county rate of twenty cents per hundred cubic feet.

Some municipal water plants supply users outside the city at the same rate charged inside the city. This frequently brings criticism upon the water department management, but it is our contention that the citizens inside the city limits were taxed for payments for

bonds for our water system, while those outside the city escaped this tax. For this reason, the consumer outside the city should pay a higher rate; and too, the cost of maintenance of distribution outside the city is usually higher, because of the difficulty in protecting mains along unpaved and ungraded streets and highways. In our case, as previously stated, the property owners of Los Angeles bonded themselves for $26,500,000 to bring this water a distance of some 238 miles and it would be an injustice to them should our Board agree to furnish consumers outside the city with water at the same rate as that paid by those inside the city limits.

While on the subject of rates, the adjustment of rate schedules, particularly if in an upward direction, is always attended by more or less discussion and controversy, prejudicial to the relations existing between the utility and the consumer; and it is therefore highly desirable that there be as few changes in rate structures as practicable. This fact makes it increasingly important that the expenditures required for construction be distributed insofar as possible, so as to require only a minimum of rate change.

Water rates should be based upon a careful study, over a period of years, of the revenue, income, depreciation, and the increasing amount of funds needed for replacements and constantly increasing operating costs. These items, being variable, make a rate revision necessary at intervals. Thus the close association of water rates and construction policies is apparent.

FIRE HYDRANTS

The Water Sales Division issues all orders for the installation or relocation of fire hydrants, although all locations must be approved by the Los Angeles Fire Department. The Fire Department pays our Water Department a flat rate of $3.00 per month per hydrant for maintenance and service charges.

The location of fire hydrants will be changed for the benefit of individuals, if they pay the cost of moving and the change in location has the approval of the Fire Department. These changes are usually requested by gasoline service stations, public markets, etc.

The splendid cooperative spirit existing between the Fire Department and our own is invaluable since our work is so closely related.

Fire protection costs us more than merely furnishing and maintaining fire hydrants. In order to assure adequate fire protection, the pumps, mains, reservoirs, and in fact the entire water system

must be larger and heavier than would be required for domestic and other ordinary use, but this is an additional indirect benefit to our citizens. In recognition of the efficiency of our water system, the National Board of Fire Underwriters has raised to a marked degree the grading of our city with relation to its fire defense and physical conditions, and a result of this enviable grading was a prompt lowering of insurance premiums.

ACREAGE SUPPLY ASSESSMENTS

In cases of application for water from newly annexed territory, they are required to pay for their own water supply—in other words, an acreage supply assessment charge. This charge is based on the proportionate cost to the department for the original expense in connection with the cost for storage reservoir, pumping equipment, and main distributing lines, on an acre basis, hence its name—as the owners of this land have not paid anything on the bonded indebtedness for the building of the aqueduct and the extra engineering expense incurred in designing a system to furnish an adequate water supply. Where an applicant desires an extension of the water main in such a territory, he is required to pay this acreage supply assessment charge in addition to the regular street main assessment charge plus the service connection charge.

MUNICIPAL IMPROVEMENT DISTRICTS

One other method of financing a water system for newly annexed districts heretofore supplied from water systems other than our municipal system, is by the formation of a municipal improvement district; and this method may be described as follows:

A formal application is made to our Board of Water and Power Commissioners to see if they have any objection to the district proceeding with the formation of a municipal improvement district and bonding themselves to cover the cost of a water system.

A representative from the Water Sales Division meets with the various committees and organizations and investigates the district to ascertain the number of consumers and the proposed boundary lines.

This information is then reported to our engineers who in turn make an estimate as to the cost of designing a complete water system. These plans and figures are then presented to the citizens of the district, usually at a mass meeting and through local press.

Petitions are then circulated throughout the district by the citizens, after which these signed petitions are filed with the City Clerk for checking. The petition is then forwarded to the City Council, and if there are no protests, the date of election is named. Our representative makes frequent visits to the district and calls on the prominent citizens and influential people, doing any preliminary work that will assist the local committee in securing a large vote for the bonds on election day.

If the result of the election is favorable, we advise them when the bonds will be sold and money available, and when work will start, as well as length of time necessary to complete.

ACQUISITION OF PRIVATE WATER COMPANIES

Private water companies operating within the corporate limits of our city, desiring to discontinue serving certain areas and anxious for the municipal water system to take over the operation of their lines with service to their consumers, may turn their system over to us under our regular form bill of sale for $1.00; providing of course, that the State Railroad Commission is willing that the private water company cease operating and approves of the arrangements for transferring their system to us.

LEASING OF CITY WATER MAINS

There are cases where private water companies are supplying water inside the city through water mains installed under the 1911 Street Improvement Act. If this area is beyond our limit of supply at the time, an agreement is entered into whereby the Municipal Water Department grants them permission to use the city's lines under our regular form of lease until such time as our mains are extended into these districts and we are able to supply them with water.

GENERAL COMPLAINTS

This, as you are aware, is a delicate subject with all waterworks men—therefore it is not my intention to dwell very extensively on the subject.

As we all know, there are always some few consumers who are not satisfied with the handling of their particular cases in the general conduct of business, and feel that they must appeal to higher authorities, and pour out their grievances to the Chief Engineer and Gen-

eral Manager, or to the Engineer of Water Works; and that is where our Water Sales Division is called upon to make a thorough investigation and return a complete report on the findings in order that the higher authorities may deal understandingly and tactfully with these dissatisfied consumers.

PUBLIC RELATIONS

The Water Sales Division enters into public relations for our organization by arranging for all exhibits and displays in connection with various meetings and conventions; arranging for speaking engagements for the Chief Engineer and General Manager before engineering clubs, civic organizations and schools; outlining program talks with moving pictures and slides, and preparing literature for distribution to the general public regarding the history and development of our water system—and this includes publicity work in widely varying proportions. For example, during the San Diego Exposition in 1935 and 1936, the Water Sales Division represented our Water Department in a joint exhibit sponsored by our Water Bureau, the Metropolitan Water District and the Imperial Valley District, where visitors passed between two gigantic cascades of water to enter a "Water Palace" where a vast panorama depicted the present and future water supplies for all of Southern California—and these projects were outlined in electric lights and described by robophone. This exhibit so thoroughly and attractively portrayed the very important part water has played and will continue to play in the development of our city and the country surrounding, that we received a special scroll of honor from the exposition officials for having one of the four outstanding exhibits.

At the American Water Works Convention held in Los Angeles last year, our Water Sales Division, at the request of your president, Mr. W. W. Hurlbut, arranged for an all day tour of our water works system, ending with a typical California barbecue under the oak trees at one of our large reservoirs. The delegates and guests remarked that the trip was not only educational from a water works standpoint, but many historic and scenic points of interest were included in the trip.

These latter activities are really outside the business of selling water but we feel that as community builders and developers, we have other responsibilities and obligations to the public—and a very important one is the cultivation of friendly working relations with the community at large.

BEAUTIFICATION PROGRAM

An outstanding example of such a service to our community is the rather well established beautification program being carried on in connection with our reservoirs, tanks and pumping plants, many of which are located in some of the best residential districts in our city. For years it had been apparent to our engineers that certain opportunities for beautification work in and around our reservoirs and various other projects were being neglected; but under the direct supervision of Mr. W. W. Hurlbut, Engineer of Water Works for the City of Los Angeles, a beautification program was organized whereby seasonable plants, trees and shrubs are so planted at these various projects, that our properties are points of interest and charm of which the citizens, as well as our Department, may well be proud.

These ornamental trees and shrubs are provided by the Bureau's propagation plant or nursery established for this purpose at our Stone Canyon Reservoir. A landscape engineer is in charge of this work and all reservoir plantings; and it is here that research work is carried on to find those most suitable and practical for use on our Department properties. The landscaping of our reservoirs resulting from this experimental work is a decided asset to the city and a source of civic pride for all of us.

The type of architecture for our pumping, chlorination and filtration plants is indicated by the buildings immediately surrounding; otherwise, the mission type of architecture predominates as we find it more in keeping with the early Spanish type so particularly appropriate here.

GOOD WILL FACTOR

The relationship between an institution and its customers is the governing factor in its success or failure. We want the public to realize that the Water Bureau has done more than furnish a water supply to the citizens of Los Angeles—it is through the development of an adequate and dependable water supply that the economic security of the community has been assured. Water is one utility for which there is no substitute; if the water supply is limited, then the growth of that city is limited in a corresponding degree.

While the public has become more critical regarding the taste and quality of the water supply and the service rendered, there is unquestionably a considerable lack of understanding relative to the technical difficulties and heavy responsibilities in connection with

the operation of a water works system. But this is one of the difficulties we are endeavoring to correct through our publicity programs; for the good will and understanding of our consumers is a valuable asset and we are endeavoring to further this spirit in every way possible. Our municipal water system is the property of our citizens and we want their cooperation and support in all our undertakings—whether large or small—and we want them to point with justifiable pride to their water system and the things it is doing to add to the health and happiness of our community.

Municipal merchandising is unlike privately owned business. Although a margin of profit must be assured to take care of charges for operation, maintenance, betterments and replacements, so that the system may keep pace with modern engineering and business practice, yet its success is measured not by the largeness of its earnings, but by the extensiveness of its service.

The policy of our water works bureau, therefore, is not to make the earning of cash dividends our main objective, but to strive to make a return to the public in lower rates, a prideful pleasure in the beauty and solidity of our structures, and in helpful relations with our citizen owners.

It is only through a thorough knowledge of the accomplishments and aims of our Water Bureau that our citizens have been able to test the efficiency of our organization and measure our services to the community. And it is the duty of each and every employee of the Water Sales Division in their direct contacts with the public, to further this spirit of friendly cooperation and thus aid in the consistent promotion and development of any activity that will benefit the community as a whole.

On the part of our executives, such a program calls for every effort for scientific research, to educate, to improve, to broaden the interchange of ideas with others in the same industry; to do all things that may give our Department a more solid foundation and more far-reaching contacts in the community, and we feel sure that we will then find on our balance sheet an asset in good will that is far more valuable than any credit in mere figures.

CREATING AND RETAINING CUSTOMERS' GOOD-WILL*

By H. L. Meites

(*Superintendent of Water, City of Chicago*)

Much has been said and written about good-will, which is, at best, a vague term. The value of good-will cannot be measured by dollars and cents, yet large sums of money have been paid for this seemingly unseen and intangible value.

What is good-will? Let us analyze briefly the psychological aspect of good-will so that we may be able to arrive at some understanding of its relative value. Will implies freedom of choice. It is not necessarily a freedom unhampered by restraint or limitation of any sort. Psychologists tell us that we are governed in the majority of our actions by prejudices and preconceptions rather than by reason. Human beings are never free entirely from rationalizations of their own modes of thought or experiences. Therefore, we may say that choice is very frequently a matter of habit. If one of two alternative lines of conduct has been chosen once, that decision, if the outcome be satisfactory, will make the same choice probable under the same circumstances in the future. We are usually said to have a free will when there do not exist restraints or compulsion from any being outside of ourselves at the time of our thinking.

Good-will is that aspect of our thinking which lends itself to a favorable judgment or choice toward a person or organization. It includes friendship, which involves a recognition of a person's qualities and a willingness to associate with him; kindliness towards objects or organizations which are more or less impersonal in character, and finally, habits that are formed upon the constant recurrence of such favorable judgment or choice. Good-will in this broad sense exists in all human relationships. Thus, we hear of good-will toward our neighbors, international good-will, and many other expressions of similar nature. In fact it ought not to be surprising to find the term so variedly used, for its natural meaning is precisely what is implied in the various fields.

* Presented at the Buffalo convention, June 8, 1937.

The human side of the present industrial progress is beginning to dawn on the consciousness of every person and is indeed cried aloud in the familiar expression of the so-called industrial democracy. It has been demonstrated in many fields that a more humane and just treatment of the employed does contribute to the increase of efficiency and the prosperity of the enterprise. Consequently, this internal good-will has become just as important as the good-will traditionally ascribed to consumers. This solidarity or friendliness of the employees is sometimes referred to as the industrial good-will as distinguished from the consumer's good-will. It was recognized as property of value by the Supreme Court of the United States way back in 1917.

There are many ways in which the interest and good-will of the water rate payers can be cultivated. The tendency persists, unfortunately, among public utility corporations, to treat the public with as little consideration as possible. In many instances I have personally observed gross abuse on the part of clerks to complaining customers. This is true, even to a larger extent, in city-owned utilities. The clerk regards the customer as merely a name or a number on the books without any personality whatsoever and when such a person comes with a complaint, real or imaginary, he treats him without sympathy. The modern well-managed public utility office today is no longer inclined to treat its customers as if they were outsiders entitled to no consideration. On the contrary, a direct and conscientious effort is continually being made to bring the customers into sympathy with the point of view and the problems of the management and, whenever possible, to persuade them to become acquainted with these problems and view them in a favorable light. Such a policy usually results in creating favorable public interest and strengthens the good-will of the consumers who come in contact with the personnel of such well-managed public utilities—private or municipally owned.

The well-informed employe is a most potent force for building good customer relations. He is all-important to any program for building customers' good-will. And unless such employees are imbued with the spirit of public service, so that their prime function is to serve the people, the reaction cannot be expected to be favorable.

The so-called "claim agent," in the old days, and not so long ago either, was expected to be hard-boiled. His standing depended

on the extent to which he could save the firm money by delay, cajolery or compromise, even on legitimate claims for shortage or inferior grade. From the standpoint of the customer's good-will, the result was extremely unfavorable. The factory or store employing such claim agents lost in bitterness and resentment more than it saved in dollars. In a certain industry, a few years ago, one firm reversed its policy. It said to its customers: "If our goods are not right, we will make them right." Just claims were settled promptly and in full. The other firms in the industry were obliged to follow suit, in order to hold their trade. To show the now prevalent standard, the Garment Manufacturers are to contest unjust returns of merchandise, unfair requests for exchange and all sharp practices. But all just claims for goods leaving the factory in damaged condition or giving unsatisfactory wear or service because of faulty construction, should be promptly and satisfactorily adjusted. One likes to deal with a firm like that. Such methods create and retain good-will. Properly guided, public opinion is a dynamic force which translates itself into good-will of inestimable value.

He who would mould public sentiment or create good-will in this changing, rapidly-moving world, must make a studious effort to be abreast of the times and interpret the happenings of the day with humane understanding. The man or woman who comes into a public office with a complaint, or seeking information and guidance, must be placed in a receptive and responsive mood in order to be served satisfactorily. Even when it is necessary to say "No," while it must be done firmly, it must also be done gently—and with a smile. We in the Bureau of Water in Chicago have found that courtesy costs nothing but pays big dividends.

DEVELOPING GOOD-WILL

To foster and maintain a spirit of good-will toward the public whom we serve, believing that courtesy is the first essential requisite, and to be at all times fair in our relations with our customers, I have posted on our bulletin board the following letter:

TO THE EMPLOYES OF THE BUREAU OF WATER

Gentlemen:

I am pleased to inform you that due largely to your efforts the number of complaints in the Bureau of Water has been greatly decreased and in order to decrease them further I shall appreciate it if you will carry out the following suggestions:

(1) Treat every customer as you would want to be treated under the same circumstances.
(2) Do not ignore or evade a question. It is better to say you don't know than to bluff or make up an answer, especially if asked about matters pertaining to the Bureau of Water; say you will find out—and do so.
(3) Never make a promise that you cannot keep or that involves another person without his knowing it. Having made a promise, do all in your power to see that it is fulfilled.
(4) Be courteous and pleasant—not gruff, snappy or perfunctory.
(5) Smile often and show that you mean it.
(6) Accept responsibility—don't "pass the buck" and don't hesitate to admit error.
(7) Do not argue, because good-will was never built up that way.

Very truly yours,
Superintendent of Water

I am a great believer in printers' ink, in putting things down black on white, for I have found that it is difficult for the average citizen to visualize, to imagine things he does not see right before him. Most of them "come from Missouri" and believe in the slogan of "show me."

The results attained have been truly remarkable. A picture here, a drawing there, all attractively displayed in the Bureau of Water puts the water-rate payer in a happy and receptive mood and then it is up to us to keep that spirit up.

I have also had a drawing made, beautifully framed, and placed in a most conspicuous place with a reflector above, making not only an attractive decoration in our office but a useful one. I have noticed, with a great deal of pride, men copying it. We have had innumerable requests for copies which we have cheerfully furnished.

OLD-FASHIONED COURTESY

Back in the days when our great-grandparents danced the stately minuet, courtesy was the watchword of the age. Today that gentle virtue is too often lost in the scramble for existence. Yet, it is easily possible to be business-like and courteous at the same time. A little more

tact, a little more care for the feelings of others, especially during these trying days, and the hand of old-fashioned courtesy extended to citizens who come to the Bureau of Water, will make this office one that will stand out from the others as a pleasant, happy place to come to.

H. L. MEITES
Superintendent of water

As I mentioned on a previous occasion, Chicago is soon to embark on a meterization program on a large scale, which will be followed by filtration. Opposition to meterization is gradually diminishing, due in a large measure to our efforts in the Bureau of Water to create good-will for meters.

We have pointed out time and again that meters do not restrict the use of water nor increase water bills. It is neither necessary nor desirable to restrict the use of water; it should be supplied in abundance and its use encouraged. We have urged property owners to keep plumbing in good repair and to eliminate useless waste thereby keeping their water bills down to a normal level. On the back of all water bills we print messages which bring home this story in a simple but effective manner, thus creating good-will and, what is more important, retaining it.

I was fortunate in having the W.P.A. arrange a project for the painting of a mural in the Bureau of Water. While it was not an easy matter the results justified the efforts. It shows on one side the misery, agony and despair brought about through the lack of water, while on the other side it shows the happiness and ecstacy of an abundance of water. It was painted by an outstanding artist who tells the story simply but graphically.

This mural has received much favorable comment and the countless thousands of water-rate payers who visit the Bureau of Water not only admire it but take along with them the lesson it tells. Another instance of creating good-will and retaining it.

Good-will is not a beautiful but rather utopian ideal. It is one of the most practical realities of social relationship. Every action brings its reaction, and in Ethics, as in Physics, action and reaction are more or less equal. Good-will, expressed in fairness, courtesy and consideration, brings in return the good-will of the customer, which is the greatest asset in any business, especially in a public office, where the average person comes "with a chip on his shoulder."

To create and retain customers' good-will in a public office one

must be especially gifted. He must be a diplomat, a mind-reader and a gentleman, and, above all, must possess the patience of a saint, the wit of a Mark Twain and the wisdom of a George Washington.

I have found that to retain the customers' good-will is even more difficult than to create it. Please a customer nine times thus creating good-will but once you fail to comply with a request, no matter how outlandish and unfair it may be, all the effort you have made to create that good-will is lost, sunk, never to come back to the surface.

Honorable Edward J. Kelly, Mayor of Chicago, is a great believer in furthering and cementing customers' good-will. In a recent bulletin addressed to all City employes he expressed the following splendid thought:

THE GOOD-WILL OF OUR TAX-PAYING CITIZENS IS THE CITY'S BEST ASSET. HELP US TO MAINTAIN THAT ASSET.

If the customers coming into contact with City or public utility employes would be willing to meet them at least part way, and be fair-minded and considerate, the task to create and retain customers' good-will would be much easier and less difficult to accomplish.

INTERNAL AUDIT AND CONTROL*

By Paul D. Williams

(*Resident Manager, Detroit, Michigan*)

(*Arthur Andersen & Co., Accountants and Auditors*)

The subject of this discussion is "Internal Audit and Control," or what is more commonly known as the "system of internal check." We will be interested in what it is, why it is necessary, and how it works, with particular reference, of course, to water companies. In every enterprise we have assets of various kinds and we must see to it that these assets are properly stored, dispensed, and used—that they are not mislaid or misappropriated. The plant and heavy equipment are usually nailed down and present no particular problem (although I recently heard of a house having been stolen from a real estate company). We are largely concerned, then, with cash, notes and securities, materials and supplies and water. If your cashier, in addition to his duties of receiving and recording the incoming cash, also posts the accounts receivable, sends out the statements, and reconciles the bank balances, he has control over both the cash itself and the various functions and records which, if maintained independently, would act as a check on the proper handling of the cash. In other words, he is not subject to internal check, and the door is open for the misappropriation of funds and for its concealment by distorting the records.

An effective system of internal check may be defined as one under which the duties of employees charged with the physical custody and handling of cash, securities, etc., are so divided from the duties of employees charged with the keeping of records (other than the cash book) as to prevent the perpetration of irregularities and their permanent concealment in the records, and to reduce the possibility of collusion to the minimum. Such a system makes it very difficult for a single employee to misappropriate cash or other assets and doctor the records so as to conceal the transaction effectively.

* Presented at the Buffalo convention, June 10, 1937.

It should be obvious that the maintenance of an adequate system of internal check is in accord with the best interests of the owners of a business. It is equally true that such a system serves the best interests of the employees. Human nature has certain well-defined characteristics; among them is the desire to be honest and loyal. But we all have degrees of strength and weakness of character, and every worker has the right to the best possible protection against his worst self. We have heard a great deal lately about companies being unfair to their employees; here is a slant which may be new to some of you. I believe that the company which makes it easy for its employees to steal is just as surely unfair to them as the company that pays starvation wages. Furthermore, under a system which does not definitely fix responsibility, an innocent employee may fall under suspicion and be unable to clear himself. Often this aspect is not fully realized. I have even heard employees object to recommendations for strengthening the system of internal control or placing them under a fidelity bond on the ground that the proposed change implied a doubt of their reliability and honesty. Such objections are shortsighted and are usually based on false pride and a lack of understanding. Oddly enough, it does not seem to occur to these individuals that such an attitude would arouse suspicion. After all, an enterprise can hardly afford to bank on the integrity of a man who is not willing to submit to ordinary business safeguards, which are for his own protection as well as that of his company. The system of internal check is designed, not only to conserve the assets and prevent fraud, but also to detect errors and produce accuracy in the accounts. One of the primary functions of any accounting department is the presentation to the management, the stockholders, and other interested parties of adequate and accurate information as to the financial position and operations of the business. The source from which such information is obtained is the accounting records; if these records are inaccurate, the value of the financial statements and reports prepared therefrom may be seriously impaired by the mistatement or omission of important facts.

An adequate system of internal check has long been recognized by public accountants as an important auxiliary to their own work. Where proper internal controls are effectively maintained, the public accountant is justified in limiting the extent of his verification of the detailed transactions. The propriety of such action has been

recognized by the Securities and Exchange Commission; in its instructions for the filing of registration statements the Commission states: "In certifying to the financial statements of the registrant, independent public accountants may give due weight to an internal system of audit regularly maintained by means of auditors employed upon the registrant's own staff. In such cases the independent accountants shall review the accounting procedures followed by the registrant and by appropriate measures shall satisfy themselves that such accounting procedures are in fact being followed."

Please note the last few words of this statement "—and shall satisfy themselves that such procedures are in fact being followed." An adequate system of internal control requires not only the establishment of proper accounting procedures and routines, but also the maintenance of such procedures in effect and their periodic revision to meet changing conditions. This requires continual supervision. The best way to maintain the effectiveness of a system of internal control is through the employment of an internal auditor or auditors whose duty it should be, among other things, to see to it that the procedures and routines established are being followed out. In this connection, it is suggested that an accounting manual be prepared, setting forth a chart of the accounts, including a description of the nature or purpose of the individual accounts and of the type of items to be charged or credited to each, and setting forth, also, the procedures to be followed in handling and recording the various types of transactions, together with the duties and responsibilities of each department or position. A copy of this manual should be given to each departmental head or group supervisor for his guidance and that of the employees under his supervision.

It is, of course, impossible to have a completely integrated system of internal control if the enterprise is small and cannot afford sufficient office employees to accomplish the necessary segregation of duties. However, even in such cases the principles involved can be put into practice to a considerable extent if the management has a reasonable amount of ingenuity and persistence.

WATER SALES

A logical place to start our survey of the internal control of a water company is to inquire into the control of water sales and the revenue from these sales. We want to be sure that all of the water which is pumped into the system is billed to customers or

otherwise accounted for within reasonable limits. We want to make certain that the meters in service are reasonably accurate, that they are all being read, and that no one is bootlegging water without benefit of meter. It is necessary, therefore, to establish a control over meters.

A permanent detailed record of meters should be maintained independent of the billing records and should be balanced periodically with the meter control account. This record should be divided as between meters in service and meters in the shop and all changes should be currently posted from set and remove orders prepared by the meter department. The section of this record covering meters in service should be so arranged as to permit of easy comparison with the meter-read books, and a continuous check of the meter record to the meter-read books should be carried on to determine that all meters in service are being read. This check might cover one section of the meter record every month or every quarter, so that over a period of a year the entire meter record will have been checked to the meter-read books.

Meter readers should not be connected with the billing department and should not make collections. The duties of meter readers usually include the reading of all meters recorded in the meter-read books and the computation of the consumption, the reporting of leaks and faulty meters, and the ascertaining and reporting of the cause of unusually high or low consumption. In addition, meter readers should be instructed to watch for and report any occupied buildings or active water connections not recorded in the meter-read books. It is highly desirable that the routes of meter readers be changed occasionally. In the case of small companies all of the meters may be read by one or two readers, making it impossible to do much switching of routes. In such cases it should be arranged to have the meters read occasionally by other employees. After the meter readers have completed a route and turned in the meter-read books, the computations of the consumption should be checked and the book turned over to the accounts receivable department for billing. Many companies today use billing machines which pick up both the old and the new readings and automatically check the computation of the consumption; where such machines are used the check prior to billing may be omitted.

After the billings have been prepared a check should be made to insure that all meters read have been billed, by totaling the con-

sumption as shown by the meter-read books and comparing this amount with the total consumption billed. If the rate structure is simple, the amount of the billings can usually be proved in total by multiplying the total consumption in each rate step by the respective rates. The total of the billings should be traced through the revenue records to the accounts receivable control account.

If the flat rate basis is used, rather than meters, the problem is, of course, quite different. In such cases it is necessary to establish routines which will record all changes in water connections and make certain that all customers are billed regularly and properly.

Many companies render their billings on a net basis with the proviso that if the bill is not paid within a specified period, the discount already deducted is forfeited. In such cases only the net amount of the bill is recorded on the customer's account. Provision should be made to accrue and record the forfeited discounts on all bills unpaid at the expiration of the discount period and thereafter no discounts should be granted except with the written approval of the proper authority.

ACCOUNTS RECEIVABLE

All entries to the accounts receivable control account, other than the revenue entires, should originate outside of the accounts receivable department. The detail customers' ledgers should be balanced with the general ledger control account every month and any differences should be traced down and corrected. Where there are a number of customers' ledgers, it is often helpful to establish subcontrols for groups of ledgers and balance the ledgers of each group to the respective sub-control at the end of the billing cycle. The balancing of the customers' ledgers to the control accounts should be periodically checked by the internal audit staff or by other employees outside of the accounts receivable department, who should also make test-circularizations of the customers' accounts. All differences disclosed by the replies should be fully and promptly investigated.

Members of the accounts receivable department should have nothing to do with the collection or handling of cash, nor should they be permitted to make allowances. All adjustments, including the allowance of forfeited discounts previously discussed, should be approved in writing by an authorized official. Charge-offs of uncollectible accounts should also be so approved, and a record of such

accounts should be maintained in a separate ledger so that they may be followed-up periodically for possible recoveries. Before writing off old accounts, it is advisable for the chief accountant to send out final collection letters, in order to make sure that accounts have not been paid and the funds misappropriated.

CASH RECEIPTS

Procedures relative to cash receipts should be designed to insure that all incoming cash is correctly recorded and promptly deposited. In this connection, consideration should be given to the proper control of remittances received by mail. The opening of the incoming mail should be a duty of a responsible employee who is not a member of the cashier's department. This employee should make a list of all receipts of checks or currency before these receipts are turned over to the cashier's department, and subsequently this list should be compared with the entries in the cash receipts book to determine that all such receipts have been recorded therein. As a matter of practical convenience, it is often sufficient if the list referred to is prepared in the form of an adding machine tape.

All mail receipts should be turned over to the cashier's department on the day received, and the afternoon mail should not be allowed to lie around over night in some desk or file drawer. This caution may seem rather too fundamental to be necessary, but it is needed in a surprisingly large number of cases. Over-the-counter receipts are often recorded by the receiving tellers by means of cash registers. The tellers should have no access to the register tapes or recording mechanisms and at regular intervals the tape totals should be checked against the amounts of receipts recorded in the cash book by an employee outside of the cashier's department. If no record is made of individual receipts other than the collection stubs of the invoices, these stubs and their controlling tapes should be filed by dates paid, and the totals of these tapes should be reconciled periodically with the related cash book entries. Collections by delinquent bill collectors should be controlled by the use of books of prenumbered receipts which should be checked against the collectors' daily reports and these, in turn, should be compared with the amounts recorded in the cash book. It is usually advisable to have the collectors obtain receipts from the cashier when they turn in their collections, so that responsibility may be fixed in the event of a shortage.

Careful attention should be given to the control of receipts from miscellaneous sources such as charges for turning off and turning on water, service installation and repair charges, sales of water to circuses, sales of scrap and surplus equipment, special assessments for main installations, interest income, rental income, etc. Arrangements should be made for reporting to the accounting department all miscellaneous sales and charges as they originate so that they may be properly recorded on the books. Accrued miscellaneous income should be computed monthly and set up on the books. These receivables and accruals should then be followed up to determine that all payments thereon are properly accounted for. Receipt books containing pre-numbered receipts with corresponding stubs or carbon copies should be used in receipting for all deposits received from customers. These should be audited periodically by someone outside of the cashier's department to determine that all receipt numbers are properly accounted for.

All cash receipts should be deposited in the bank intact, preferably upon the day received, and, in any case, not later than the following day. Duplicate deposit slips should be obtained for all deposits and it is often desirable to arrange with the bank to return the duplicate slips direct to the comptroller or auditor rather than to the cashier. Test comparisons of these duplicate slips can then be made with the individual items appearing in the cash receipts record to determine whether there has been any substitution of items to make up shortages.

As previously mentioned, neither the cashier nor any of the employees under his supervision should have custody of, nor access to, the general ledger or the detail customers' ledgers; neither should members of the accounting department be used as relief cashiers. This segregation of duties is fundamental to the system of checks and balances which we are discussing.

CASH DISBURSEMENTS

It was said previously that all receipts should be deposited intact. The corollary to this principle is that all cash disbursements should be made by check or from separate petty cash imprest funds—never from general receipts.

Checks should be serially numbered and any voided or cancelled checks should be retained in order that all checks can be accounted for. As a safeguard against alteration, the checks should be printed

on protected paper and wherever possible the amounts should be inserted with a check protector. Checks should be prepared only upon the authority of properly approved invoices, vouchers or other adequate authorization and should be cross-referenced to the invoices or vouchers which they pay. A complete record of all checks issued should be made daily in the cash book or check register. Checks should be signed, or at least countersigned, by an official ranking above the supervisor of disbursements. All checks when presented for signature should be accompanied by the supporting vouchers and the responsible official should satisfy himself that the vouchers are properly approved and the checks in agreement therewith before signing the checks.

We have previously mentioned that minor cash expenditures should be made from a petty cash imprest fund. All disbursements from the fund should be evidenced by signed petty cash vouchers which should be made out in ink as a measure of safeguard against alteration after payment. The petty cash fund should be carried at a fixed amount and should be reimbursed periodically by a check drawn on the general bank account. The authorization for the reimbursement check should be accompanied by a supporting petty cash voucher, which should be reviewed and finally approved by some official ranking above the cashier. These petty cash vouchers should then be cancelled by perforation or otherwise before being filed, in order to guard against their being again presented for reimbursement at a later date. As a precaution against unauthorized disbursements, advances to employees, etc., surprise counts of the petty cash fund should be made from time to time by the internal auditor.

Many companies have on hand miscellaneous funds such as unclaimed wages, key deposits, employees' savings funds, etc., which are not recorded in the general books. Often the custody of such funds is entrusted to the cashier on the theory that he is the logical person to have charge of all monies. This procedure is inadvisable since the presence of these extraneous funds in the cashier's department provides a source out of which shortages in the bank accounts or the petty cash may be covered, at least temporarily. Such funds and the liability therefore should usually be set up on the books, and the funds should be deposited in the bank or placed in the custody of individuals who have no access to the general cash.

It is very important that the monthly reconciliation of the bank

accounts be made by the internal auditor or by employees who are independent of the cashier's department and who do not sign checks. Such reconciliations should include an examination of the canceled checks for signature and endorsement and a comparison of the checks with the disbursements record as to date, payee, and amount. In addition, all unusual items should be traced back to the voucher or other authority for disbursement. Footings of the cash book should be proved; all check numbers should be accounted for; and total deposits, per books, should be reconciled with the total of deposits shown by the bank statement. Cash transfers between banks should be traced to be sure that both sides of the transactions are recorded without an undue lapse of time. Officers and employees who sign checks or handle cash, securities, or valuable materials should be adequately bonded. Securities should be under the dual control of two executives, preferably a treasury official and an accounting executive.

PURCHASING AND ACCOUNTS PAYABLE

All purchases should be made by the purchasing agent or purchasing department against signed requisitions from the various departments, and should be evidenced by the issuance of formal purchase orders. Copies of the order should be furnished to the receiving clerk and to the accounting department. When the goods are received the receiving clerk should check the quantities against his copy of the purchase order and should fill out a receiving slip. This slip should be forwarded to the accounting department for matching with the invoice. When the purchase invoices are received they should be compared with the file copy of the purchase order and with the receiving slip as to quantities, price, delivery charges, terms, etc. The clerical accuracy of footings and extensions should be checked and the account distribution shown. Provision should be made for indicating on the face of the invoices that they have been properly audited and by whom. After entry in the purchase record or voucher register, the approved invoices should be forwarded to the disbursements department for payment.

Safeguards should be established against the passing of duplicate invoices, either by permanently attaching the purchase order and receiving slip to the invoice or by noting on the receiving slip that an invoice has been received and passed. When the invoices are paid the date of payment and the check number should be entered

thereon as a precaution against duplicate payment. Any returns of goods to vendors should be covered by returned material tickets and should be followed up to see that proper credit is received.

One form of disbursement which is often lacking in proper safeguards is postage. Where the quantity of outgoing mail is large, consideration should be given to the use of postage meters or precancelled stamps.

PAYROLLS

Padding payrolls is one of the most common forms of embezzlement; therefor careful attention should be given to the procedures governing the hiring of employees, the preparation of payrolls and the preparation and distribution of pay checks or envelopes. If the company is large enough to afford it, these three functions should be divided among three different employees or departments.

All hiring of new employees should be done by the employment or personnel department upon written requisitions signed by department heads. The employment department should keep a complete record of all employees, independent of the payroll records. This record should show classifications, salary or wage rates, and other pertinent information. The duties of timekeeping, preparation of payrolls, and distribution of the labor charges are usually performed by the payroll department. This department should be advised in writing by the employment department of changes in rates and of employees hired or released. Changes in the payroll records should be made only on such authorization. A daily report of the time worked by each employee should be prepared by the timekeepers and at the end of the pay period the total time as per the timekeepers' reports should be checked against the number of hours shown by the employees' clock cards, if time clocks are used. Provision should be made on the timekeepers' reports for showing the job or account distribution of the daily labor charges. At the end of the pay period the summary of the labor distribution should be made up simultaneously with the preparation of the payroll and the two totals balanced before the payroll is released. After the payroll has been completed, it should be submitted to the controller or other responsible official for approval and then turned over to the paymaster for preparation of the checks or pay envelopes. If employees are paid by check, such checks should be drawn on a special payroll bank account to which is transferred an amount equal to the total

of the payroll; if payment is made in cash, a check for the amount of the payroll should be cashed and the funds turned over to the paymaster. Paychecks or envelopes should be distributed to the employees by the paymaster and his assistants; they should *not* be turned over to the timekeepers or foremen for distribution to the men. Signed pay receipts should be obtained for all wages paid. Any unclaimed wages should be returned to the general bank account within a reasonable time and the liability therefor should be set up on the books.

Internal audits of payrolls should be frequent and thorough and should include (1) a comparison of the payrolls to the employment department records as to names and wage rates and a check of receipts for wages; (2) a check to the time records to verify the hours worked; (3) verification of extensions and footings; (4) a check that the payrolls have been properly approved, and (5) independent reconciliation of the payroll bank account, including a comparison of the cancelled pay checks to the payrolls.

INVENTORIES

Satisfactory control of materials and supplies is usually accomplished through the maintenance of perpetual inventory records which are periodically balanced with the control account in the general ledger. Materials and supplies should be in the custody of a responsible storekeeper and should be issued only against requisitions signed by the foremen or other authorized employees.

Routines should be devised for the proper reporting and handling of salvage materials, and the internal auditor should check the retirement work orders in order to make sure that the salvage which should have been realized was properly accounted for. Physical inventories of sections of the materials and supplies should be taken at frequent intervals under the supervision of the internal auditor or representatives of the accounting department and such physical counts should be checked by them against the perpetual inventory records. Any discrepancies of material amount should be fully investigated. All adjustments of the inventory records and controlling account to bring them into agreement with the physical inventories should be approved by a responsible official.

GENERAL

Again let me emphasize the fact that the principles of internal control apply alike to large and small companies; where the office is

too small to permit the required segregation of duties, the chief accounting officer must assume the responsibility of policing the system through various test-checks and surprise examinations.

In both large and small companies a regular program of vacations for office employees is, for obvious reasons, an important part of the system of internal control.

This is by no means an exhaustive list of the points to be covered in maintaining an adequate system of internal check, but it is hoped that the more important ones have been touched on. Every company has its own methods of doing business and the system of internal check should be tailor-made to fit each particular case. The principles involved are simple and logical and can be applied by any one who has a fund of common sense, pointed up by an instinct for "checks and balances" and backed by a thorough knowledge of the methods and procedures of his company.

A well integrated system of internal control is a really lovely thing in its symmetry and balance. It is worked out logically and results in a sense of poise and sureness in the organization as a whole.

A word of caution in closing—do not make the mistake of supposing that such a system, once it is properly set up and running smoothly, will continue to function automatically. It is necessary for the internal auditor, or some one fulfilling his function, to be eternally test-checking all phases of the work to be sure the proper practices are not lost sight of and to adapt the accounting methods to changing conditions.

Discussion by E. C. Schwier.* Mr. Williams did exceedingly well in his discussion of the subject "Internal Audit and Control." It is true that since time began we have had with us the problem of misappropriation of funds, and no doubt we have had, to some extent, methods of trying to control this condition. I do believe, however, that recently we have given more thought to this subject than in former years, principally because we have tried to put the problem of internal check on a systematic basis.

Mr. Williams has very ably set forth the major items and departments which require constant watching, and has laid the groundwork for a workable internal check system in any organization, large or small. There are, of course, conditions arising in different companies which require different methods of handling, but with

* Auditor, Indianapolis Water Co., Indianapolis, Ind.

very little thought and time these can be worked into the control system very easily.

It is true that many companies cannot maintain an elaborate system. There are, in my opinion, probably three classifications of business. The first is the small business, in which one or two persons in the organization probably do the work of office manager, bookkeeper, cashier, and collector. It is very difficult in a company of this kind to have an elaborate system of internal check, but in such cases it would be well worth while if that company would employ a firm of accountants to install a system of accounting procedure and practice and then periodically have the same firm of accountants check the records of these individual employees.

The second group is what may be considered the middle class, where there are a number of persons in a well organized accounting department. In such an organization, the responsibility for checking the other employees can be so distributed as to obtain a very good internal check.

The third is the larger companies which employ, in their own organization, accountants whose duty it is to make these internal checks and to see that the system originally adopted is consistently followed.

It is my opinion that the idea of installing a system of internal check is primarily for the purpose of avoiding misappropriation of funds or doctoring the records. In a great many cases errors are found in accounting practice which do not come under the classification of theft. These errors might be found without an internal check system, but with one they probably will be discovered sooner than otherwise. Hence the internal check system offers an advantage in all such cases, as well as in cases of theft.

In an organization where the personnel turnover is slow, where employees remain in the same position over a long period of time, the work in all departments becomes more or less mechanical, and although these employees may be doing a good job, there is a tendency for them to become set in their ways. By having a system of internal check, and by having someone new coming into the job periodically checking the records, the person making the check is in a better position to offer suggestions for improvements which the employee doing the work day by day may not have thought of, and at the same time keep the department up to the full capacity of efficiency.

In organizing a system of internal check it is important first to determine whether or not your accounting systems are workable. I believe that every system should be organized around a sufficient number of persons so as to provide for all safety. Any system which involves more persons than are actually required for safety has a tendency of defeating the purpose for which it is intended. Also, if something goes wrong it becomes difficult to place responsibility.

I remember that in our own organization several years ago we worked up a system for paying off employees who had been laid off between work periods. In working up this system it was the intention to avoid having these laborers call at our office for their final pay. The system which was eventually adopted required eight separate persons to handle these transactions before the employees finally got their money. It is only reasonable to believe that where this many people handle one transaction more than half of the operations are of minor importance. In these minor operations one clerk with ordinary intelligence can concentrate on his particular function in the transaction and find a way to get himself what he thinks is easy money. This happened in our company, but the unfortunate employee was caught the first time he tried it and the system was immediately changed so that fewer persons are involved and responsibility more centralized.

So it is my opinion that it is the duty of the accountant who has charge of the records first to organize in his company a system of record keeping and reports which is not too elaborate, but which is complete in the information desired. Then he must set up a well organized internal check system to follow through.

"CAN A MUNICIPAL WATER WORKS BE ECONOMICALLY OPERATED?"*

By Wendell R. LaDue

(Chief Engineer & Superintendent)

(Bureau of Water Supply, Akron, Ohio)

"Can A Municipal Water Works Be Economically Operated?" It is believed that little reluctance will be found among you and other Water Works men in answering this question in the affirmative. However, upon due consideration, not being a legal question, an unqualified "yes" cannot be given.

I hasten to explain: Let us look to the dictionary definition of the word—

> "Economical—Careful and provident in management; not wasteful or extravagant; frugal; saving. Example: "No government will be just, *economical*, or efficient, unless the general opinion of the people requires that it be so." Nordhoff's 'Politics for Young Americans'—Ch. 4, P 19."

Mr. Nordhoff's example may seem harsh and unduly critical when applied to us as water works officials. However, is it not true? Does not the public opinion after all very often control or at least restrict municipal economies?

> Public opinion is mass desire expressed by individuals or groups either by personal contacts or thru ordinances, charters, municipal codes or other types of controlling legislation. In the main, water supplies, municipal or private, are affected in their functions by the type and quality of the municipal consciousness.

How often have we, as individual operators or managers of water works, wished we could do the things John Smith does in his home town. We are forced to the realization that public opinion for a given community, although not a tangible thing, nevertheless is mobile, changeable, restless and, beyond doubt, a specific force pecu-

* Presented at the Central States Section Meeting, August 20, 1937.

liar to that community. Hence each community has its own inborn, inherited ideas concerning its own activities. These are hard to change, even though the citizen may roam far and learn much, he is rarely convinced and changed but little. It is a practical factor of the homing instinct and a natural derivative of civic pride. The citizens of a community in general get what they want, good or bad, whether it be in matters of sewage disposal, parks, playgrounds, schools, taxes or water works. Hence a water department, considered entirely adequate and economically operated by one community, may be seriously lacking in the eyes of its neighbor or of the stranger within its gates.

Of 12,000 plants in the United States today, serving 65 percent of the country's population, 80 percent are municipally owned. With this vast field in which to work, it is indeed unfortunate that to date no nation-wide survey of water supply administration and operation practice is available. As water works men we are by no means agreed on the extent so called "service-to-the-community" shall be carried in ordinary operation and maintenance before we find ourselves indulging in what the community may choose to call "luxuries." Unfortunately, perhaps too often, service is measured in terms of cost to the consumer as indicated by his water bill. We often hear the expression "Your rates are too high" given without any logical reason or reasonable attempt at comparison of the city's problems with those of other communities. In one community, the painting of fire hydrants; in another, the purchase of new automobiles; in another, the furnishing of office quarters; in another, the station grounds; all in turn may be considered to be too unnecessarily prominent, or expensive, or elaborate. These accusations, if you please, are not the idle talk of a few, but in known instances, are sources of concerted attack on the part of citizens or public officials fighting in the name of economy. Let us not be hasty, therefore, in condemning a superintendent for apparent laxity in maintenance. His fight for efficiency in his community may be one calling for tactful education of a public, which in the past few years has very greviously felt the need of those clamoring for the bare necessities of life. However, through it all, let it be said to the credit of water works men, water supplies have been kept safe and essential maintenance preserved.

Too true it is that in times of financial stress, debt services are met regardless of how much may be left for the regular items of

operation and maintenance. The town credit is said to be at stake, and forced economies are the rule. Opposed to such methods, where debt services are easily met, who can deny that "Where abundance rules, economy is a stranger."

Does it follow that economy is never found in cities having little or no financial problem? We are forced to believe upon casual comparison and observation, that such is the case, but, of course, in varying degrees. If *public* opinion believes rates are fair, and service adequate, a larger personnel may be carried; embellishments of plant and equipment made; and so-called luxuries indulged in which in many towns could not be suggested, much less tolerated or actually placed in effect. Note that the writer does not desire to mark down a plant which can afford the best; he maintains that it can be had only when public opinion acquiesces.

Many factors enter into the picture which cannot be reduced to universal "dollars-and-cents" logic, namely—Morale of Organization, Cooperation of Local Government, Political Interest of the Party in Power, Monetary Status as Compared to Other City Departments, Physical Aspects of the City (particularly rate of growth), Age of Plant, Source of Supply, Wage Levels, Satisfactory Public Relations and Opinions, Public Confidence, Favor of the Press, and kindred items

It is essential that these factors be considered in each individual case, for in the end a satisfied community is the best indication of an efficient enterprise. It behooves each of us, therefore, to help mold and direct public opinion in his community so that the best in water works management will be required.

We are badly in need of a broad, popular, public understanding of the meaning of "Water Supply." Realizing the deep significance of the human element on this question, let us attempt to deal with specificities for sake of clarity, and ask ourselves:

What is the prime purpose of a water supply system? We answer: To deliver a safe, potable water in sufficient quantities and at adequate pressures for all ordinary essential domestic, industrial and fire protection uses in an economical manner and at a cost consistent with safe operation and with assured continuity of service.

To what does all this bring us? Simply to the fact that to judge plant operating efficiency, one with another, comparisons, however odious or difficult, must in some manner be made. In all such

studies, a definite "yardstick" is lacking and we find almost as many measuring systems as there are water systems.

Here truly is a real task, which in a way is now being considered by a committee of the American Water Works Association. Allow me to quote from Mr. Chatters—speaking before the recent Buffalo Convention: "You will never have comparable information until you have *more* fully agreed on terminology and *quite* fully agreed on basic accounting principles."

In any "yardstick" for the determination of operating efficiency, we do not believe that the cost of financing past or future construction should be included. This factor embraces far too many controversial and uncontrollable elements and should not be charged against an operating manager's statement of expense. Great stress has been given in recent months on the "pay-as-you-go" plan. In other words, the financing of reconstruction and new construction, through bond issues, is being discarded in favor of financing from revenue.

Equipment changes, due to obsolescence, are generally minimized due to the long life and dependability of water works types and design. Thus the question of replacement is not very often foremost in the minds of water works men, even though greatly increased efficiency may result. In municipal affairs, in general, great reluctance is expressed to the scrapping of equipment, however long or well it has lived its economic life-span. Too often a near catastrophe must occur, before the necessary approval is gained for replacement. Charges for such improvements should not be considered as maintenance items, although the Glossary of Terms of the proposed "Water Works Manual" defines maintenance as—"the upkeep of the utility plant so that it may operate at its fullest efficiency." If reproduction, due to obsolescence, is required, let its cost be removed from the picture by its classification as an "asset" account and not one of operation and maintenance.

Let us therefore confine, as well as define, operating expense as that expense necessary to the *maintenance* (but not reproduction) of the enterprise; the *rendering* of the services for which operated; the *sale* of merchandise; the *processing* and *disposition* of commodities produced, and the *collection* of the revenue.

The accounting methods to achieve a "yardstick" as a measure for economy of operation are matters of prime importance to water works men who desire to evaluate their own methods by comparison with others who they have reason to believe are operating highly

efficient and successful enterprises. We may be agreeably, or disagreeably, surprised by comparisons directed toward our own plant, but, in the interests of unbiased progress, great good can be done.

The writer sincerely trusts that he has not developed the idea that municipal plants are not, or cannot be, operated successfully and economically. We are quite fully aware that hundreds of them are so operated with little desire for gain or praise, except that which comes from the realization and knowledge of a task well done. Rather does he desire to impress upon the water works man the innate desire to look into each item of operation of his own plant; to seek to find the medium for comparison of his plant with others; discarding the bad; adopting the good; passing along to the other fellow a spirit of constructive criticism and cooperative goodwill.

ANALYSIS OF AKRON OPERATION

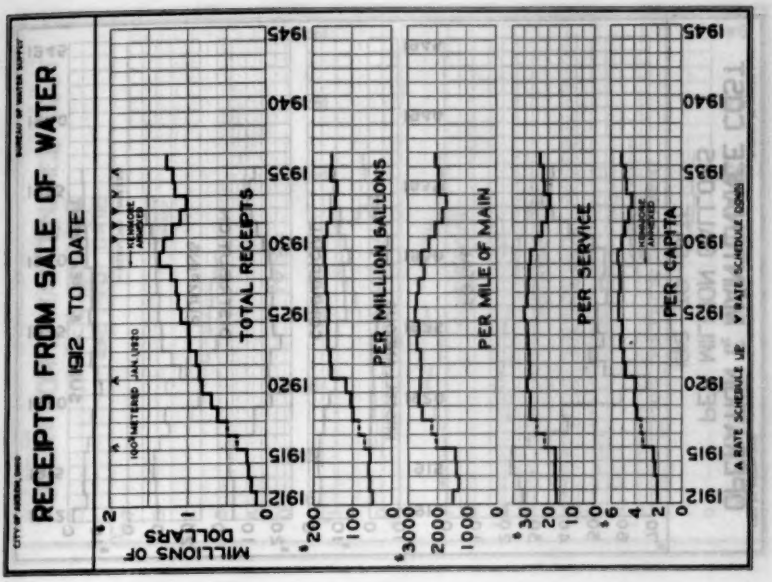
The ideas above-mentioned have been followed in preparing a series, of graphs which will be useful in comparing plants with that operated at Akron, Ohio. We believe the graphs, in general, to be self-explanatory. The terms: "Expense per Million Gallons"; "Expense per Mile of Mains" and "Expense per Service" are used because it is believed these terms are at present more readily applicable to numerous other plants with the use of a minimum of accounting.

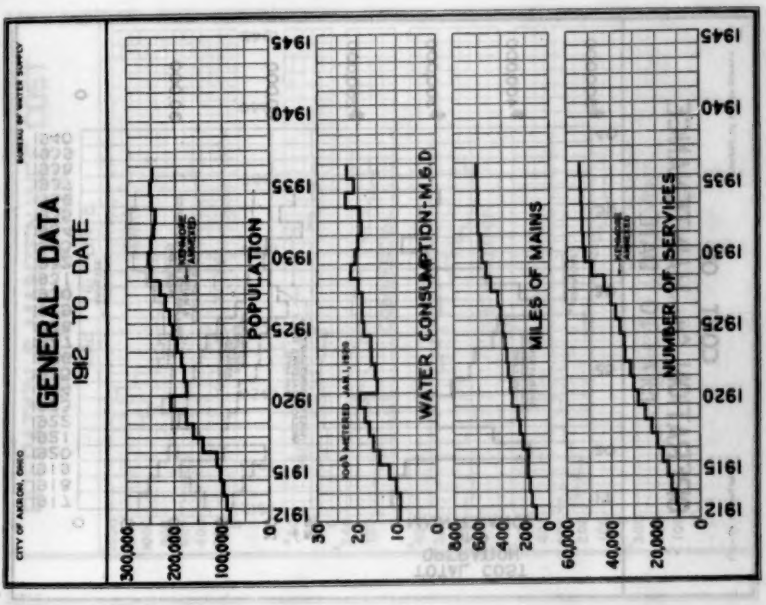
Water Supply was inaugurated at Akron, Ohio, as a private enterprise, in 1881 and continued as such until April 1st, 1912, after which date it became a municipally-owned and operated system.

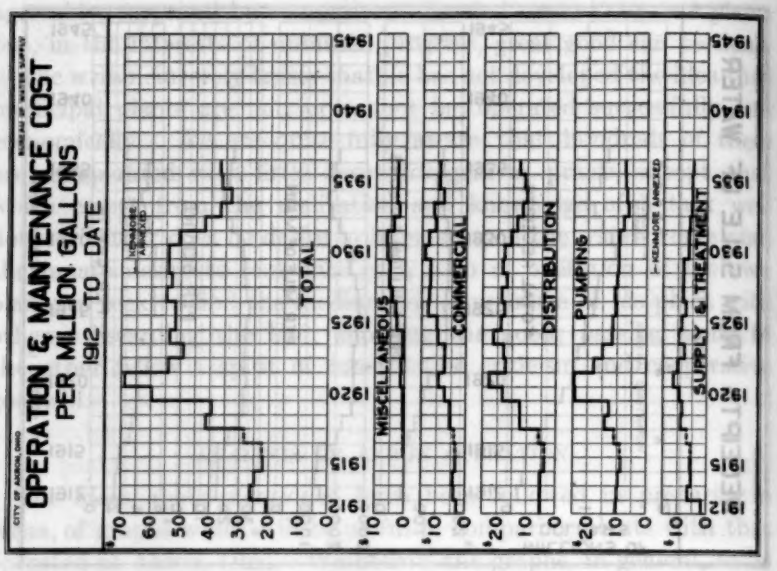
Akron in 1910 had a population of 69,000; in 1920, 208,000; an increase in 10 years of 139,000, or 202 percent. Akron was what now could be termed the "Dionne of Industrial Cities." Along with physical growth came an appreciation of the ideals of purity and quality required in water supply. The old supply, not being able to qualify, was abandoned and a new source was developed and controlled, which, with easy, progressive development, can be enlarged to care for a city many times the present size.

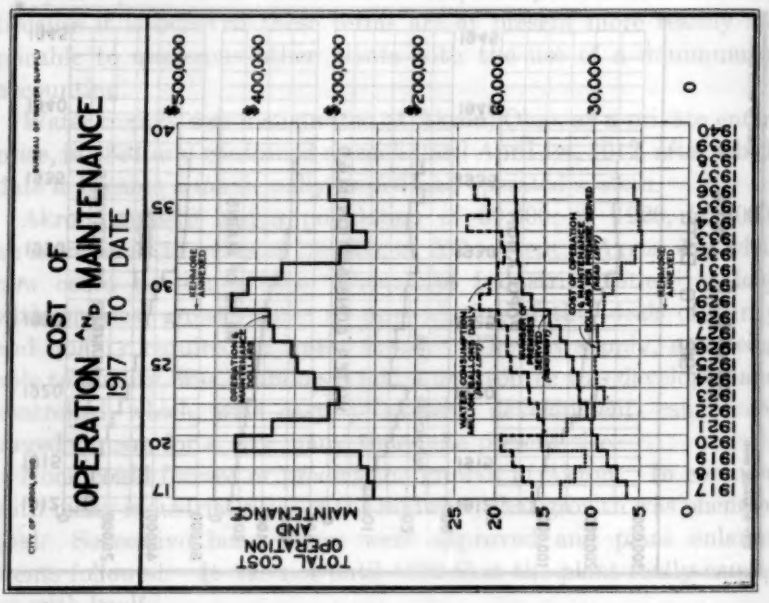
None could foresee or predict the growth of Akron. In common with many industrial cities of the midwest, that growth was phenomenal. Successive bond issues were approved and plant enlargements followed. It was not until 1930 that the plant really caught up with itself.

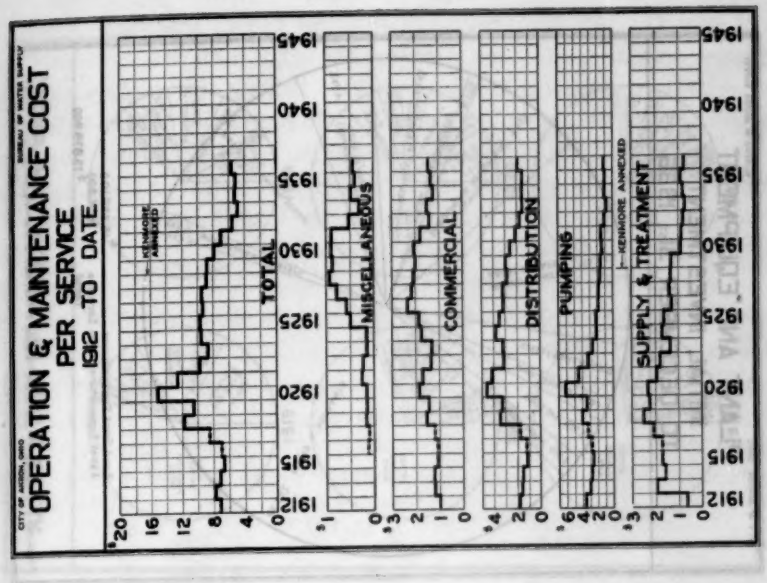
With the limitations prescribed by 25-year serial bonds, pyra-

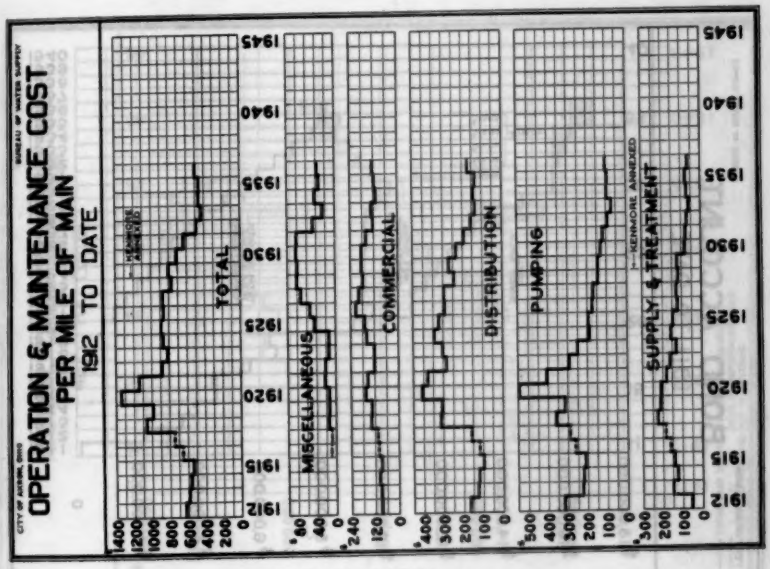

CITY OF AKRON, OHIO
BUREAU OF WATER SUPPLY
RECEPTS FROM SALE OF WATER
1912 TO DATE
MILLIONS OF DOLLARS
TOTAL RECEPTS
PER MILLION GALLONS
PER MILE OF MAIN
PER SERVICE
PER CAPITA
1912
1915
1920
1925
1930
1935
1940
1945

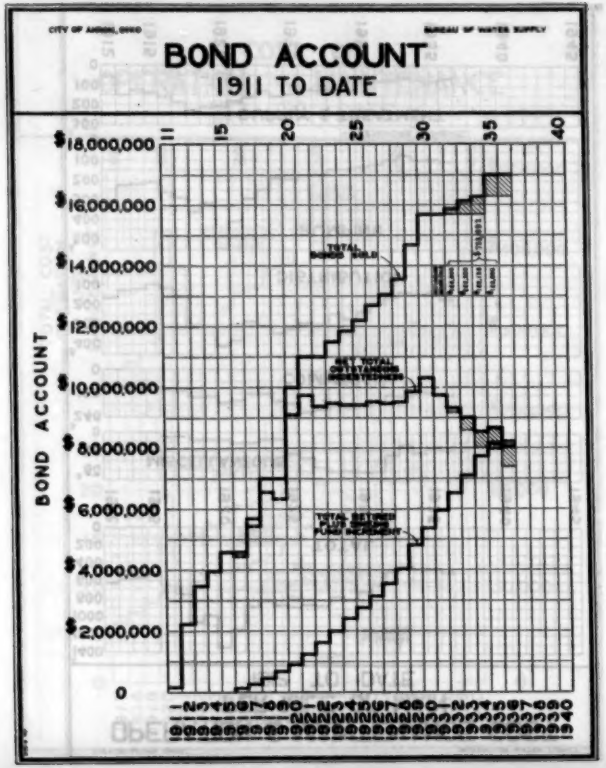

CITY OF AKRON, OHIO
BUREAU OF WATER SUPPLY
GENERAL DATA
1912 TO DATE
POPULATION
WATER CONSUMPTION-M.G.D.
MILES OF MAINS
NUMBER OF SERVICES
1912
1915
1920
1925
1930
1935
1940
1945

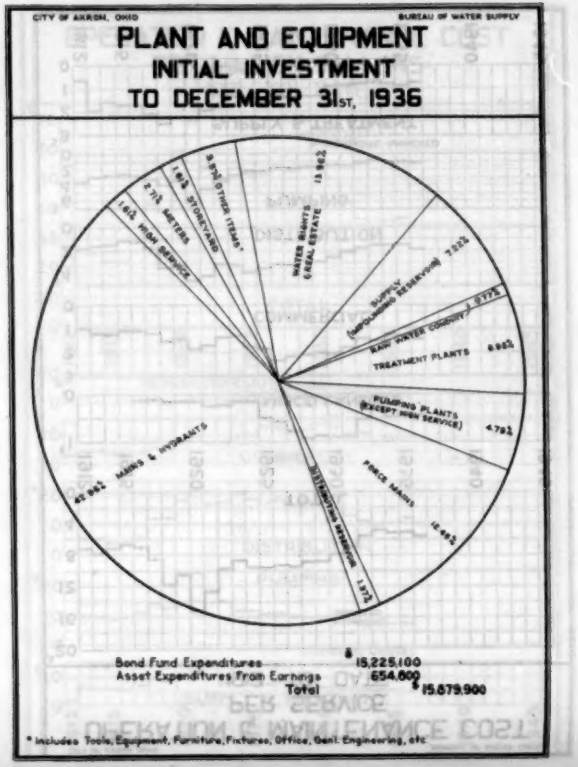

CITY OF AKRON, OHIO
BUREAU OF WATER SUPPLY
OPERATION & MAINTENANCE COST
PER MILLION GALLONS
1912 TO DATE
TOTAL
MISCELLANEOUS
COMMERCIAL
DISTRIBUTION
PUMPING
SUPPLY & TREATMENT
1912
1915
1920
1925
1930
1935
1940
1945

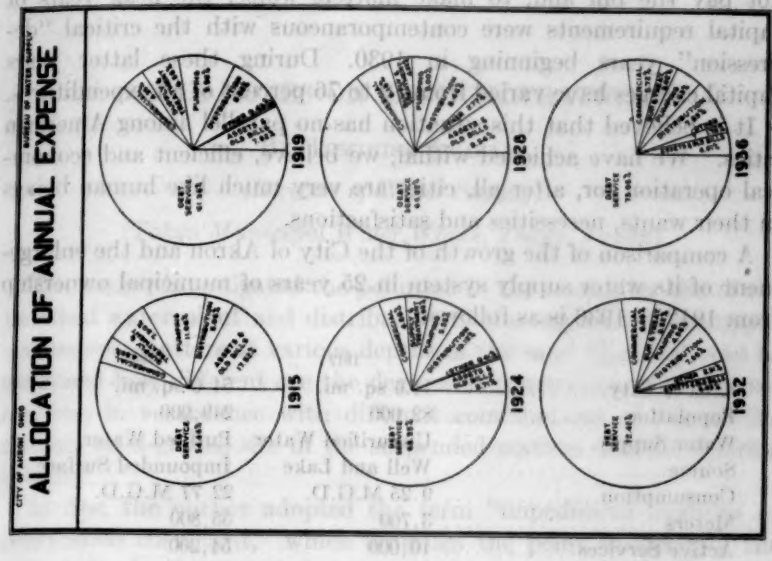

CITY OF AKRON, OHIO
BUREAU OF WATER SUPPLY
COST OF
OPERATION AND MAINTENANCE
1917 TO DATE
TOTAL COST
OPERATION
AND
MAINTENANCE
$500,000
$400,000
$300,000
$200,000
60,000
30,000
0
1917
1940

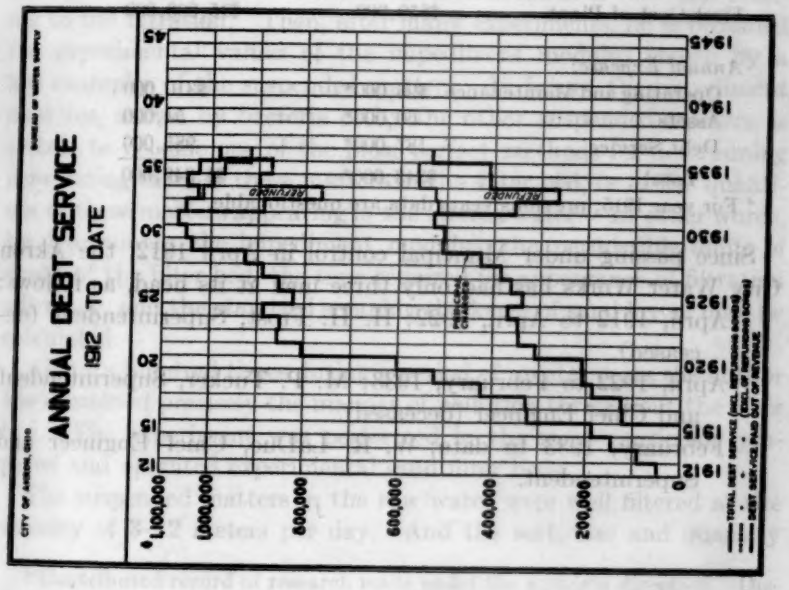

OPERATION & MAINTENANCE COST
PER SERVICE
1912 TO DATE
TOTAL
MISCELLANEOUS
COMMERCIAL
DISTRIBUTION
PUMPING
SUPPLY & TREATMENT
KENMORE ANNEXED
1912
1915
1920
1925
1930
1935
1940
1945


OPERATION & MAINTENANCE COST
PER MILE OF MAIN
1912 TO DATE
TOTAL
MISCELLANEOUS
COMMERCIAL
DISTRIBUTION
PUMPING
SUPPLY & TREATMENT
KENMORE ANNEXED
1912
1915
1920
1925
1930
1935
1940
1945


CITY OF AKRON, OHIO
BUREAU OF WATER SUPPLY
BOND ACCOUNT
1911 TO DATE
BOND ACCOUNT
$18,000,000
$16,000,000
$14,000,000
$12,000,000
$10,000,000
$8,000,000
$6,000,000
$4,000,000
$2,000,000
0
11
15
20
25
30
35
40
TOTAL BONDS SOLD
NET TOTAL OUTSTANDING BONDS REQUIRED
TOTAL NET BONDS PAID (SINKING FUND REQUIRED)


CITY OF AKRON, OHIO
BUREAU OF WATER SUPPLY
PLANT AND EQUIPMENT
INITIAL INVESTMENT
TO DECEMBER 31ST, 1936
13.96%
WATER RIGHTS (REAL ESTATE
7.22%
SUPPLY (IMPOUNDING RESERVOIRS)
3.97%
RAW WATER CONDUIT
8.86%
TREATMENT PLANTS
4.79%
PUMPING PLANTS (EXCEPT HIGH SERVICE)
1.47%
PUMPING EQUIPMENT
16.48%
MAINS
42.96%
MAINS & HYDRANTS
1.62%
HIGH SERVICE
2.71%
METERS
1.86%
STORE YARD
8.92%
OTHER ITEMS*
Bond Fund Expenditures $15,225,100
Asset Expenditures From Earnings 654,800
Total $15,879,900
* Includes Tools, Equipment, Furniture, Fixtures, Office, Gen. Engineering, etc.


CITY OF AKRON, OHIO
BUREAU OF WATER SUPPLY
ALLOCATION OF ANNUAL EXPENSE
1915
1919
1924
1928
1932
1936


CITY OF AKRON, OHIO
BUREAU OF WATER SUPPLY
ANNUAL DEBT SERVICE
1912 TO DATE
$1,100,000
1,000,000
800,000
600,000
400,000
200,000
0
45
40
35
30
25
20
15
10
1945
1940
1935
1930
1925
1920
1915
1912
REFUNDED
REFUNDED
PERIODIC CHANGES
TOTAL DEBT SERVICE (INCL. OFF-HIGHWAY BONDS)
DEBT SERVICE PAID OUT OF REVENUE

miding of capital charges was to be expected; but expectation did not pay the bill and, to make matters worse, the peak years of capital requirements were contemporaneous with the critical "depression" years beginning in 1930. During these latter years capital charges have varied from 70 to 76 percent of all expenditures.

It is believed that this situation has no parallel among American cities. We have achieved withal, we believe, efficient and economical operation for, after all, cities are very much like human beings in their wants, necessities and satisfactions.

A comparison of the growth of the City of Akron and the enlargement of its water supply system in 25 years of municipal ownership from 1912 to 1936 is as follows:

	1912	1936
Area of City	11.6 sq. mi.	54.0 sq. mi.
Population	82,000	249,000
Water Supply	Unpurified Water	Purified Water
Source	Well and Lake	Impounded Surface
Consumption	9.25 M.G.D.	22.77 M.G.D.
Meters	3,700	55,800
Active Services	10,000	54,200
Fire Hydrants	450	5225
Mains	113 miles	616 miles
First Cost of Plant	$850,000	$15,900,000
Annual Expense:		
Operating and Maintenance.	$96,000*	$310,000
Assets	60,000*	54,000
Debt Service	187,000*	985,000
Total	$343,000*	$1,349,000

* For year 1915; previous years data are questionable.

Since passing under Muncipal control in April 1912, the Akron City Water Works has had only three men at its head, as follows:

April, 1912 to April, 1922; H. H. Frost, Superintendent (deceased).

April, 1922 to February, 1933; M. P. Tucker, Superintendent and Chief Engineer (deceased).

February, 1933 to date; W. R. LaDue, Chief Engineer and Superintendent.

SOME NOTES ON SAND FILTRATION*

By Tomihisa Iwasaki

(Director of Water Supply)

(Tokyo Municipal Water Works, Tokyo, Japan)

The author investigated the pollution in the sand filter bed of the practical water plant and distribution of the organic and inorganic microscopic matters at various depths of the sand filter bed; and he examined how different are the degrees of penetration of suspended matters, in accordance with different combinations of size of the filtering sand-grains, size of the suspended matters and the filtering velocity.

At first the author adopted the term "impediment modulus or penetration coefficient," which indicates the point of arrest of the various kinds of suspended matters in the raw or unfiltered water during filtration; and he worked out several kinds of formulae relating to the filtration. Then, after many experiments, he determined the experimental values of the impediment modulus shown by a few examples of the suspended matters. In future the impediment modulus, shown by bacteria or by the other suspended matters, is certain to become one of the most perfect methods for determining penetrating rates of these matters in the filter bed, or of the quantities of these matters appearing in the filtered water. In other words, by determining the impediment modulus, the permissible limits of depth of the filter bed, the time required for appearance of filtration efficiency, and the standard scraping thickness of sand layers may be calculated.

About a hundred times during a period of several years the author has examined precisely the manner of pollution throughout the filter bed. The experiment was performed in the most cautiously prepared and operated experimental sand filter beds.

The suspended matters in the raw water were well filtered at the velocity of 3–12 meters per day. And the sort, size and quantity

* Contributed record of research made under the author's direction. Discussion by Prof. J. J. Slade and Prof. W. E. Stanley at request of Editor.

of the suspended matters, arrested among the sand layers, were observed by means of the microscope. Then the author endeavored to reveal the impedimental characteristics of these suspended matters and their variations.

For identifying and measuring the microscopic matters in the raw or unfiltered water, the materials were concentrated by means of the centrifuging tubes, and were researched microscopically under the blood-corpuscles counting apparatus. This method is now being supplementarily used, under the author's direction, in the examination of water quality in every water purifying plant of Tokyo Water Works.

Considering that the probability of impediment may increase parallel to filling up meshes of the sieves with the small particles in the raw water during filtration, the author has established a formula, indicating the impediment modulus of these small particles when they were being filtered by the sieve mesh. Then this formula was applied to indicate filtration mechanism in the sand filter bed.

The impediment modulus may gradually increase during filtration according to the filling up of void spaces in the sand layer. Thus another formula was determined by which this increase might be calculated.

Those fundamental formulae are as follows:

(i) $\dfrac{\partial I}{\partial z} = -\lambda I$ .....Relation between depth (z) of the sand bed and number or quantity of the microscopic matters in the filtrating water (I).

(ii) $\dfrac{\partial I}{\partial z} + \dfrac{\partial S}{\partial y} = 0$ .....Continual relation in filtration

(iii) $\lambda = \lambda_o + cS$ .....Increase of impediment modulus (λ)

(The figures [symbols] used are the same as are explained later.)

From the first two formulae, based upon and solved by the third, various kinds of approximate equations were obtained, by which the quantity of microscopic matters in the filtered water, at each depth of the sand bed, might be approximately calculated.

Some of these approximate equations, obtained from the fundamental formulae, are as follows:

$$\lambda = \lambda_o + \lambda_o \delta \rho$$
$$I = I_o \rho \{1 - \delta(1 - \rho)\}$$
$$\delta = cI_o y$$
$$\rho = e^{-\lambda_o z}$$

Here y = filtration time (day)
z = depth of the sand layer (cm.)
λ = impediment modulus
λ_o = initial impediment modulus
c = coefficient of impediment modulus
I_o = quantity of microscopic matters passing through the area 1 cm.^{2} of the uppermost surface of the sand bed in a unit of time (individual number/cm.^{2}/day)
I = quantity of microscopic matters reached the area 1 cm.^{2} at a certain depth (z) of sand bed in a unit of time. (individual number/cm.^{2}/day)
S = quantity of microscopic matters arrested in 1 cc. of the sand at a certain depth (z) of the bed in a certain time (individual number/cm.^{3})

Judging from his long series of experiments, the thicker the sand layer, the more effectively the bacteria and other suspended matters (except ultra-microscopic bacteria and colloidal substances) may be arrested among the sand layers. And it is also suggestable that among the layers of ordinary sand filter plants a greater number of the bacteria in the raw water may almost entirely be arrested.

It takes a much longer time, even in the case of the minute bacteria in the raw water, to pass the sand layer into the filtrate than in the case of the water itself; and, strictly to say, the bacteria which appear in the filtered water may be those which existed in the raw water several days or more before (and those newly created), near the bottom of the sand bed. Thus the fact, that variations of the germ numbers in the filtered water are much less than in the raw water, may be clearly explained.

We must acknowledge that the filtration efficiency, in which the germ numbers in raw and filtered waters are calculated and compared at the same time is still obscure in meaning.

These phenomena of variation in germ number somewhat resemble those which are detected in the relation between volume of falling water and of flowing water in the nature, previously reported in this publication (issue of February, 1935).

Next, the author tried, about 80 times, experiments of 100 to 150 minutes' filtration, using white Potter's clay and other matters which were microscopic, and filtering them through layers, which consisted of ordinary mixed sands or sieve-analysed and perfectly washed sands, at the slow filtering velocity of from 3 to 10 meters per day. In every experiment he calculated the impediment modulus of these microscopic matters by measuring practical quantity of the matters at various depths of the sand bed.

In finding the impediment of white Potter's clay when filtered through given sand, it was dried up and well mixed in the tap water, and thus the artificial raw water was prepared, after which it was applied to from 2 to 5 small filtering apparata. The progressive changes in pollution of the sand layer were then examined at certain intervals of time. In the course of these experiments, care was taken to keep the volume of white Potter's clay mixed in the raw water and that arrested in the sand bed at almost equal values. The filter sands used were taken from the ordinary water plant in Yodobashi, Tokyo Water Works, and were ordinarily mixed or sieve-analysed by Tyler's meshes No. 14–28, 28–48, 48–80 and 80–100; and in the later examinations of bacteria filtration, No. 100–200 was also used. The filtering velocity was from 3 to 10 meters per day. Besides the white Potter's clay a few kinds of micro-organisms were also taken as materials. Experiments on Colon Bacillus and a coccus are now being carried out, but results have not yet been obtained because there were quite different phenomena from those seen in the experiment with white Potter's clay, etc.; and calculations were much confused owing to the remarkable multiplication of the bacteria in the sand. Based upon the results of experiments, he adopted the following equations, in which the impediment modulus (λ), the initial impediment modulus (λ_0) and the coefficient of the modulus (c) are calculated.

Impediment modulus:

$$\lambda = \frac{1}{(z - z') \log e} \cdot \log \frac{S}{S'}$$

Initial impediment modulus:

$$\lambda_0 = \frac{\lambda_2 S_{01} - \lambda_1 S_{02}}{S_{01} - S_{02}}$$

Coefficient of impediment modulus

$$c = \frac{\lambda_1 - \lambda_2}{S_{01} - S_{02}}$$

or

$$\lambda_o = \frac{[S_0^2][\lambda] - [S_0][S_0\lambda]}{n[S_0^2] - [S_0]^2}$$

$$c = \frac{n[\lambda S_0] - [S_0][\lambda]}{n[S_0^2] - [S_0]^2}$$

here λ_o = initial impediment modulus; value of impediment modulus when $S = 0$

S_o = quantity of microscopic matters arrested in a certain time in a unit volume of sand at the surface of the filter bed (individual number/cm.^{2})

S = quantity of microscopic matters arrested in a certain time in a unit volume of sand at a certain depth of the filter bed (individual number/cm.^{3})

n = number of times of experiment

The experimental values of c and λ_o obtained from these equations are given in table 1.

Although the colon bacilli show in the sand layers considerable change in their germ numbers, owing to their remarkable multiplication and death; this change seems to influence λ_o and c, because theoretically there is no difference in values of λ_o and c between before and after multiplication.

Examining the experimental values, the author established the equations between impediment modulus (λ_o), velocity of filtration (v) and size of the sand (D). For example, he proposed following empirical expressions for the B. coli filtration, the sand being sieved uniformly:

$$\lambda_o = \frac{1.297}{v^{0.299}}\left(\frac{341}{D} - 1\right)$$

$$c = \frac{0.475 \times 10^{-9}}{v^{0.365}}\left(1 + \frac{923}{D}\right)$$

D: Size of Sand grain in μ

He recognized that the calculated values nearly coincide with the experimental values.

The impediment modulus above considered, certainly deals with a fundamental problem in filtration engineering, the investigation

TABLE 1

1		2	3	4	5	6	7
Accounts.....		λ_0			C		
Meshes of sieves		48-80	80-100	100-200	48-80	80-100	100-200
Average size (μ) of sand.....		227	160	104	227	160	104
Material	Filtering velocity (m/d)						
Colon bacillus	3	0.100	0.291	0.512	0.080×10^{-9}	0.096×10^{-9}	0.110×10^{-9}
	5	0.095	0.240	0.480	0.070×10^{-9}	0.076×10^{-9}	0.098×10^{-9}
	7	0.080	0.224	0.450	0.060×10^{-9}	0.070×10^{-9}	0.090×10^{-9}
Meshes of sieves		28-48	48-80	80-100	28-48	48-80	80-100
Average size (μ) of sand.....		829	417	227	829	417	227
Material	Filtering velocity (m/d)						
White potter's clay	3	0.53	0.66	0.74	2.25×10^{-9}	2.57×10^{-9}	2.70×10^{-9}
	5	0.47	0.57	0.62	2.15×10^{-9}	2.35×10^{-9}	2.30×10^{-9}
	7	0.43	0.49	0.55	2.10×10^{-9}	2.50×10^{-9}	2.20×10^{-9}
	7.5	0.38	0.43	0.50	2.00×10^{-9}	1.60×10^{-9}	2.10×10^{-9}
	10	0.34	0.42	0.48	1.70×10^{-9}	1.85×10^{-9}	2.10×10^{-9}
Meshes of sieves		14-18	28-48	48-80	14-28	28-48	48-80
Average size (μ) of sand.....		829	417	227	829	417	227
Material	Filtering velocity (m/d)						
Scenedesmus	3	0.55	1.67	1.99	0.25×10^{-3}	0.21×10^{-3}	0.07×10^{-3}
	5						
	7	0.52	1.23	1.40	0.03×10^{-3}	0.07×10^{-3}	0.03×10^{-3}
Fragilaria	3	1.50	3.90	5.10	0.05×10^{-3}	0.02×10^{-3}	0.09×10^{-3}
	5	1.50	3.37	5.30	0.06×10^{-3}	0.01×10^{-3}	0.06×10^{-3}
	7	1.20	2.60	3.60	0.09×10^{-3}	0.05×10^{-3}	0.03×10^{-3}
	10	1.15	2.19	2.20	0.15×10^{-3}	0.04×10^{-3}	0.12×10^{-3}

of which has hitherto been neglected. Also this modulus seems to give an important principle for preliminary experiments in deter-

mining the filtering velocity, in connection with the author's new method of microscopical investigation for the quality of raw and filtered water.

The filtering efficiency, E or $\frac{No - N}{N}$, will be expressed by the following equation:

$$E = 1 - e^{-\lambda z}$$

So called impediment modulus has intimate connection with filtering efficiency, as

$$\lambda_o = \frac{1}{1 - E_0}$$

in which E_o is the value of filtering efficiency.

The "impediment modulus" will vary according to the filtering velocity, and it is certainly an important indicator of the characteristics of filtered water, of filtration efficiency and of the degree of penetration of bacteria and other suspended microscopic matters through the sand filter layers.

APPENDIX

Soshi-Ritsu (in Japanese) or Impediment modulus; der Verhinderungs-modulus; le modûlus dempechement may be called too Coefficient of penetration; der Durchdringungs-koeffizient; coefficient de penetration.

Rate of retaining; der Zurückhaltungsgrad; le prix de retenirement or Index of retardation; der Abhaltungsanzeiger; l'index de retardment.

DISCUSSION

Discussion by J. J. SLADE, JR.:* The supreme object of the scientific investigator is to determine the laws that control the entities he observes so that he may be able to predict their actions with precision. Ultimately these laws must be expressed as mathematical formulae. Often these formulae are empirical; they are based simply on the numerical relations observed in the gross process. Sometimes, however, they will be deduced logically from fundamental principles that may be recognized underlying the process. The latter more desirable procedure, so well illustrated by Tomihisa Iwasaki's

* Associate Professor of Engineering Mechanics, Rutgers University.

paper, requires a sound and ready knowledge of mathematical processes which, unfortunately, is not generally possessed by the Engineer.

In discussing Iwasaki's important work it has seemed to me that I could render a service by translating his formulation of the problem of filtration into ordinary language. For the sake of clearness it seems desirable to divide this discussion into two parts, that dealing with retention by the filter of inert matter, and that dealing with retention of bacteria.

INERT MATTER

Iwasaki's fundamental equations are i, ii, and iii. (For brevity (*I*) will henceforth be called the flow and (*S*) the density.) The first equation states that the decrease in flow through a lamina of thickness *dz* is directly proportional to the flow entering the lamina; in other words, that the amount of matter arrested in a lamina is proportional to the amount that goes in. This is a very simple statement, almost axiomatic, and hardly controvertible as a working hypothesis.

This relation holds, of course, only so long as the condition of the filter bed remains unaltered; but the filter changes, for, as time goes on, the voids in the sand are slowly filled by the polluting matter, which itself acts as a new filter. Mathematically this means that the value of the proportionality factor, λ, of Equation i changes in time. Equation iii states that the change in the proportionality factor is directly proportional to the density of matter filling the voids; that is, as the voids fill up, the resistance to flow increases. This, too, is a simple and reasonable working hypothesis.

Equation ii is a statement of a different sort. This says that the decrease of flow through a lamina is equal to the increase of the density therein. It says, in effect, that matter is neither created nor destroyed in any region of the filter bed, that the increase in density is fully accounted for by the matter that is lost to the flow. The first two statements, though very reasonable, are hypothetical to some extent; they may be called the laws of filtration. There is nothing hypothetical about this latter statement; it simply limits the problem to stable, inert matter: matter that neither disintegrates out of the field of vision nor precipitates into it. Most inorganic suspensions would be allowed by this qualifying equation, at least for practical purposes.

Having stated the two filtration laws (Equations i and iii) and the delimiting relation of continuity (Equation ii) between flow and density, it is next necessary to find explicit expressions for these quantities in terms of depth and time. It is very difficult to obtain exact solutions for these differential equations, but Iwasaki has obtained some approximate solutions. By an explicit solution of the system of differential equations we mean, of course, an equation from which we can compute the flow of matter (say) at any depth z at any time y, when we know the character of the filter, the nature and concentration of the pollution, and the rate of filtration. In the final equations there appear two constants, λ_o and c, which must be determined experimentally. Through long and careful experiments Iwasaki has determined these constants for a wide range of working conditions, and these are given in the tables presented in his paper.

It may be of interest to those who find it difficult to visualize an algebraical expression to examine one of these final formulae graphically. The most important is $I = I_o\rho\{1 - \delta(1 - \rho)\}$. For the sake of illustration we may take the polluting matter to be white potters' clay sorted in the interval 28–48 (Tyler's meshes) filtering through sand of average grain size 829 μ at the rate of 7.5 m/d. From Iwasaki's tables we find, corresponding to these conditions, $\lambda_o = 0.38$, $c = 2.00 \times 10^{-6}$. We may also assume $I_o = 108$ particles/cm.^{2}/day—this number being taken merely to simplify computation. Using the tables of exponentials in Eshbach' *Handbook of Engineering Fundamentals* we may determine any number of values of the flow corresponding to values of z and y. The four curves of the figure have thus been computed. Curve (1) is for the initially clean sand, $y = 0$; curves (2), (3), and (4) are for y = 2, 5, and 10 days respectively after the beginning of the process.

Curve (4) presents an interesting phenomenon. It seems to indicate that ten days after the beginning of the process the pollution is completely arrested at a depth less than 2 cm. below the surface of the filter. Before coming to this conclusion, however, it is necessary to examine the degree of approximation of the equations obtained by Iwasaki. These final equations approximately satisfy the differential equations from which they were derived only when the product $\delta = cI_oy$ is less than unity. As y (and hence δ) increases, so does the error between the approximate and exact solutions. Though it is difficult to obtain the exact solution, it is not difficult to determine some of its general properties. One of these is that

all the curves have the general form of the first three shown in the figure. Instead of cutting the zero axis, as Curve (4) does, it should bend more or less sharply and follow close to the axis as indicated by the broken line. Even so the pollution would be practically arrested between 2 and 3 cm. below the surface.

Is this really true? The answer is that it is true if the conditions of the problem remain unaltered. But it seems unlikely that these conditions will remain unchanged. For one thing, by the time complete arrest takes place the filter will be clogged and the passage of the water itself will be impeded so that the rate of filtration will no

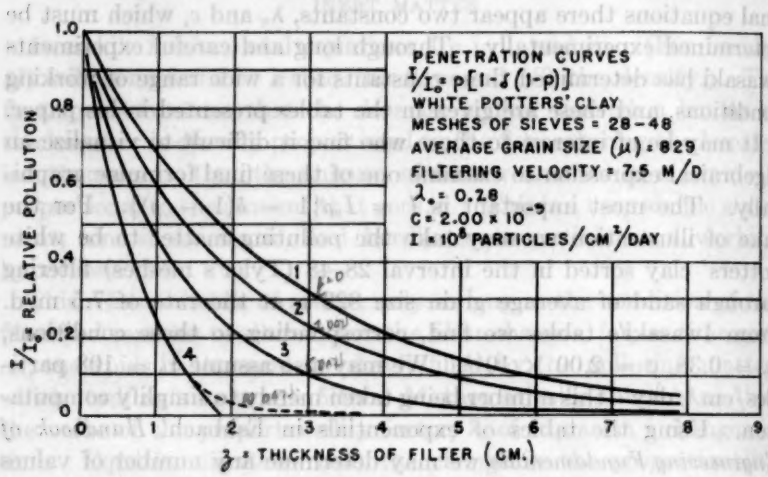


FIG. 1

longer be 7.5 m/d. The mathematical solution will not be at fault; the conditions of the problem will have changed.

It must also be mentioned that these approximate solutions are valid only when the filter is initially clean and when the flow of pollution through its surface is constant.

BACTERIA

Iwasaki's two laws of filtration should apply to any type of polluting matter. The continuity relation (Equation ii) cannot, however, apply in the case of living organisms except for times of filtration during which the multiplication of bacteria is inappreciable. Ordinarily the increase in the density of the matter arrested will be due not only to the decrease of flow but also to new matter created

in the lamina. In order to take into account the "remarkable multiplication of the bacteria in the sand" noted by Iwasaki, Equation ii must be replaced by some other statement.

It might seem at first that this is a hopeless task, but the statistical growth of cultures has been carefully studied and the autocatalytic chemical reaction has been successfully applied to the description of this growth.* Assuming autocatalytic action, the following equation is suggested instead of Equation ii, when the polluting matter is bacteria:

$$\text{(iv)} \qquad \frac{\partial I}{\partial z} + \frac{\partial S}{\partial y} = \frac{4b}{a^2} S(a - S)$$

This equation attributes the density increase in a lamina both to the decrease in flow and to the natural multiplication of the organisms. Here a is the maximum density to which the bacteria will grow in the medium and b the undisturbed rate of growth when the colony has attained one-half its maximum growth. An equation such as this will eliminate the changes in the constants, λ_o and c, noted by Iwasaki in the case of bacteria.

I make no attempt to obtain approximate solutions for this new set of differential equations, lacking the guide of experimental results. It is to be hoped that Iwasaki will soon publish the results of his experiments. He is to be congratulated on his painstaking experimental labors and his reduction of the problem to fundamentals.

Discussion by WM. E. STANLEY:† In these "Notes on Sand Filtration" Tomihisa Iwasaki has presented an interesting preliminary discussion of certain experimental work on the penetration into the sand bed of microscopic materials including colloidal matter and bacteria for slow sand filters and has endeavored to reduce the observations to mathematical formulae.

The contribution, apparently, is an effort to briefly summarize the results of much laborious work on the part of Tomihisa Iwasaki and his associates, in which more than the usual attention has been given to mathetmatical considerations. The author seems to consider that his experimental data supports his mathematics for various quantities of inert material (White Potter's Clay), but that more

* See, for instance, T. B. Robertson, *The Chemical Basis for Growth and Senescence*, J. B. Lippincott Co., 1923, Philadelphia.

† Professor of Sanitary Engineering, Cornell University, Ithaca, N. Y.

experimental data will be required for colloidal matters, particularly bacterial growths. He explains part of the difficulties by the statement "calculations were much confused owing to the remarkable multiplication of the bacteria in the sand." It is to be hoped that these studies will be continued until a closer agreement may be found between theoretical analyses and experimental results. Greater detail in the presentation of experimental data would be helpful.

The rates of filtration used, 3 to 12 meters per day (3.2 to 12.9 million gallons per day per acre) are within the normal range of operation of slow sand filters. The results of these experimental investigations may prove quite helpful in the development of our technical knowledge of the mechanics of the operation of sand filters. It would be of especial interest if the studies could be extended to higher rates of filtration such as are used in rapid sand filters.

The results of observations of penetration of floc and fine material into experimental rapid sand filters by Messrs. Armstrong and Allan have recently been published. (Proceedings, A.S.C.E., December 1936) Armstrong and Allan have endeavored to relate the penetration of floc to the sand size and to some extent the shape and character of the sand grain. M. Tomihisa Iwasaki has gone farther and by bringing in the microscope and the bacteria counting apparatus he has endeavored to consider and evaluate more of the many variables in the complex inter-relationships existing between the factors which control the filtration of water through sand beds.

Patient scientific workers like M. Tomihisa Iwasaki with their tedious and laborious efforts deserve a great deal of credit and should be encouraged to continue their investigations. It is within the realm of possibilities that in due time a team of highly trained and properly equipped scientific men may be able to analyze the water characteristics, the filtering media characteristics and determine with mathematical exactness the results which may be obtained under a given set of conditions or for any number of different sets of conditions.

It is not so easy for the practical minded engineer to anticipate with confidence that these scientific developments can be applied on a practical scale so that the many complications due to the fickleness of mother nature may be neutralized or provided for and a filtered water produced with greater comparative economy than with less refined methods.

EXPERIENCES WITH ACTIVATED CARBON AT HAMMOND, INDIANA*

By Leo Besozzi[1] and J. C. Vaughn[2]

In June 1936 preliminary to initial operations at its new water purification plant, the Hammond Water Department, through its supervising engineer, undertook to set up a complete specification for the purchase of all chemicals required for the operation of the plant. The Notice to Bidders, Instructions to Bidders, Proposal, Contract, Specifications, and Performance Bonds were patterned along the same lines as construction work is handled by the Department. This method of purchasing chemicals, however, did not prove very popular and considerable discussion and explanation was entered into concerning its merits and demerits with prospective bidders but in spite of all objections to this form of bidding, a substantial number of bids were received on all chemicals; the largest number of bidders being those bidding on activated carbon.

Preliminary investigations on the water to be treated indicated that a substantial amount of carbon would be used at the plant and since it also appeared that the yearly expenditure for this particular chemical would in all probability exceed that made for other chemicals, all available data were consulted to determine how this specification could best be set up. It might be pertinent to add at this point that the carbon requirement for the first year of operation of the plant will aggregate approximately 625,000 pounds, costing about $25,000, and exceeding the estimated requirements by about 400 percent.

A review of the available literature on carbon, including the preliminary drafts of the report of the Committee on Water Purification Chemicals, together with what information could be obtained from those who had experience with the material, and plant practices elsewhere, lead to the conclusion that while it might be desirable to

* Presented before The Water Purification Division at the Buffalo Convention, June 8, 1937.

[1] Supervising Engineer, Department of Water Works, Hammond, Indiana.

[2] Chemist, Department of Water Works, Hammond, Indiana.

consider fineness, density, and other physical properties of the material, the most substantial basis upon which it could be evaluated was on the basis of its adsorption property or in other words its phenol value.

SPECIFICATIONS

It was on this basis that the specifications were written; the most pertinent parts relating to carbon being set forth as follows:

Excerpts from Carbon Specifications of Hammond, Indiana Water Department

1. For furnishing and delivering complete as specified, pulverized Activated Carbon in railroad car lots, packed in ..... containers and having a phenol value of ....., the unit price of no dollars and ..... cents ($) per pound.
2. It is the intention of these specifications that the bidders' statements made in the proposal regarding the quality of the material offered shall constitute a guarantee to the Board of Trustees that the material will at all times be of such quality; therefore in the event that any bidder after award of contract, furnishes any of the material which, upon test, is found to be of lower quality than was offered in his proposal, the Board of Trustees will either reject the material or penalize the bidder by a reduction made in his unit bid price per pound. No bonus is offered under these specifications if the bidder actually furnishes better quality material than that indicated in his proposal as the bidder is in all cases not meeting a definite standard but is being allowed to set his own standard.
3. The calculation of penalties shall be as follows:

   In the event that the phenol value of the carbon furnished is found by test to be *more* than the value stated by the Contractor in his proposal, the material will either be rejected or the contractor will be penalized as follows:

   Multiply the contract price by the phenol value stated by the contractor's proposal. Divide the result by the phenol value of the material as received without drying the sample. This result is the evaluated bid price in the case of carbon found to have a greater phenol value than was bid and is the price that will actually be paid to the contractor by the Board of Trustees.

4. The Contractor shall furnish a performance bond in the sum of the total amount of the contract (unit price per pound bid, times the estimated number of pounds as stated in the Instructions to Bidders) guaranteeing that he will furnish and deliver the materials stated in his bid for a period of one year at the prices stated in his bid and guaranteeing that the materials will be delivered within the time limits stated in the bid and of the quality stated in the bid. Under the guarantee, the Contractor hereby agrees to make good without delay, at his own expense, any failure to deliver the materials within the time limits set forth in his bid and to make good any materials of a quality inferior to the materials as offered by his bid, the engineer of the Hammond Water Department to be the judge at all times of the quality of said materials. Under this guarantee the Contractor also hereby agrees to keep and save harmless, the Board of Trustees of the Department of Water Works, from all liabilities, judgments, costs, damages of any nature whatsoever that might come against said Department of Water Works because of any act of the Contractor in the execution of this contract. Under this guarantee the Contractor also agrees that the unit prices set forth in his bid shall constitute the total unit price cost per pound that the said Department of Water Works will pay for all materials received and that these prices are guaranteed to remain unchanged by the said Contractor during the period of this contract which shall be one year from the execution date thereof.
5. The composition of the material will be determined by analyzing samples taken promptly upon the arrival of the material at the Hammond Filtration Plant. The samples shall be so taken as far as is practicable so that they will represent an average of all parts of the shipment from top to bottom and shall not contain a disproportionate share of the top and bottom layers. All samples taken shall weigh at least ten (10) pounds and shall be mixed thoroughly and "quartered" to provide two samples of one pound each, one of which will be used for the immediate testing at the laboratories of the Hammond Water Department and the other of which shall be kept care-

fully sealed for use in a possible retest as provided hereinafter.

At least five (5) percent of the number of containers shipped will be sampled. They will be taken from various parts of the shipment, dumped, mixed and sampled as stated above. The sampling operations will be conducted as expeditiously as possible in order to avoid undue exposure of these materials to the air. After samples of these materials have been taken they will be divided as stated above an immediately placed in air tight containers. One sample will then be tested by the laboratories of the Hammond Water Department and the other stored carefully sealed for a possible retest as provided hereinafter.

Written notice of dissatisfaction with a shipment of any of the materials based on these specifications will be placed in the hands of the contractor not later than ten (10) days after the receipt of the shipment at the Hammond Water Filtration Plant. If the contractor desires a retest he shall notify the engineer within five (5) days of the receipt of notice of the complaint. The remainder of the sample used by the Hammond Water Department for test purposes and the sample stored for use in the case of a retest will then be forwarded to a laboratory agreed upon by the engineer and the Contractor and a new test made, the results of which will be accepted as final.

The expense of the retest and the expense of forwarding of all samples to the laboratory for retest will in all cases be borne by the Contractor.

6. The adsorption efficiency of the carbon will be based upon its phenol adsorption. The phenol value which shall be stated by the bidder in his proposal, is the parts per million of the carbon required to reduce phenol in solution from one-tenth (0.1) to one hundredth (0.01) parts per million. The water used for testing will be distilled water, free from all substances which might interfere with the test. The time of stirring after addition of the carbon shall be two (2) hours and the agitation shall be sufficient to impart a velocity to the water of approximately one foot per second. The velocity of the tip and

of the agitator blades shall not be greater than one and two tenths (1.2) nor less than eight tenths (0.8) feet per second. At the end of the two hour stirring period enough of the solution shall be filtered through paper and tested for residual phenol by the Baylis-Gullans modification of the Gibbs method or other methods equally accurate.

On June 8th, 1936, after duly advertising, the Department of Water Works received four bids for carbon which are set forth below:

BIDDER	PRICE PER POUND BID CARLOAD LOTS	PHENOL VALUE	EVALUATED BID PRICE ON BASIS OF PHENOL VALUE OF 20	EVALUATED ESTIMATE OF YEARLY COST
A	$0.0495	(20)	$0.0495	$9033.75
B	0.0511	(16)	0.04088	7460.60
C	0.0495	(20)	0.0495	9033.75
C	0.047	(25)	0.05875	10721.87
C	0.04325	(30)	0.0648	11826.00
D†	0.040	(20)	0.040	7300.00*

* Found later to be about 400 percent too low.

† Award made.

On July 23rd, 1936, the first shipment of carbon was received at Hammond and on July 27th, 1936, the regular treatment of water with this chemical began; the pre-determined policy of the plant being that at all times the plant effluent was to have a threshold odor value of three (3) or lower, and in no event would the threshold odor value of the plant effluent be allowed to go above three (3).

In order that the reader may form some conception of the taste and odor problem at Hammond, it would be pertinent at this time to set forth the characteristics of the water being treated.

The city of Hammond, located on Lake Michigan at the extreme northwest corner of the State of Indiana in the "Chicago District" and in the center of the industrial "Calumet Region," has taken its water supply from Lake Michigan for over a period of forty years and for about twenty-five of these years did not in any way treat the water. The lake has proven to be one of the most marvelous natural sources of water supply but unfortunately has also proven to be the most convenient place to dispose of sewage and industrial wastes. As the population of the Calumet Region and the Chicago

Districts has increased and the growth has been an extraordinary one, the marginal waters of the lake have become so seriously and extensively polluted that no city at the present time could safely take water from the lake without extensive treatment to make it both safe and palatable for drinking purposes.

In a great many instances the treatment of sewage has been undertaken to protect the shore waters of the lake but the cities along the lake in Indiana, because of negligence in this matter, have rendered the marginal waters of Lake Michigan between Chicago and Michigan City, Indiana, in a state of grosser pollution than any other locality in the entire Great Lakes.

RAW WATER CONDITIONS

Analyses of the raw water being treated at Hammond show the following characteristics:

Color. Lake Michigan water is essentially free of dissolved color but colored industrial wastes in suspension are frequently found. Large areas of the lake in the vicinity of the intake often show a heavy oil film on the water. Large patches and streaks of industrial wastes are common, together with floating garbage dumped off the Hammond intake by Illinois cities.

Temperature. The temperature of the water varies from 32°F. to 82°F., minimum temperatures beginning in December and carrying through the winter and then rising to maximum temperature in August.

Turbidity. The turbidity is relatively low during the greatest portion of the time (approximately 10 p.p.m. or under) but excessive turbidity occurs during times of on shore winds. During these periods the turbidity may go as high as 250 p.p.m.

Hardness. The hardness of the water is fairly constant ranging from 120 to 130 p.p.m. and while softening at Hammond was considered, it was not deemed necessary.

Alkalinity. The alkalinity of the water is likewise fairly constant varying from 106 p.p.m. to 117 p.p.m. with a pH of 7.7 to 7.9.

Iron and CO_2. Only traces of these elements are found in the water.

Bacteria. This problem is a serious one and it was evident from the start that the plant would at all times have to combat a heavy bacterial load resulting from human wastes. In 1924 an investigation of the pollution of Lake Michigan by the United States Public

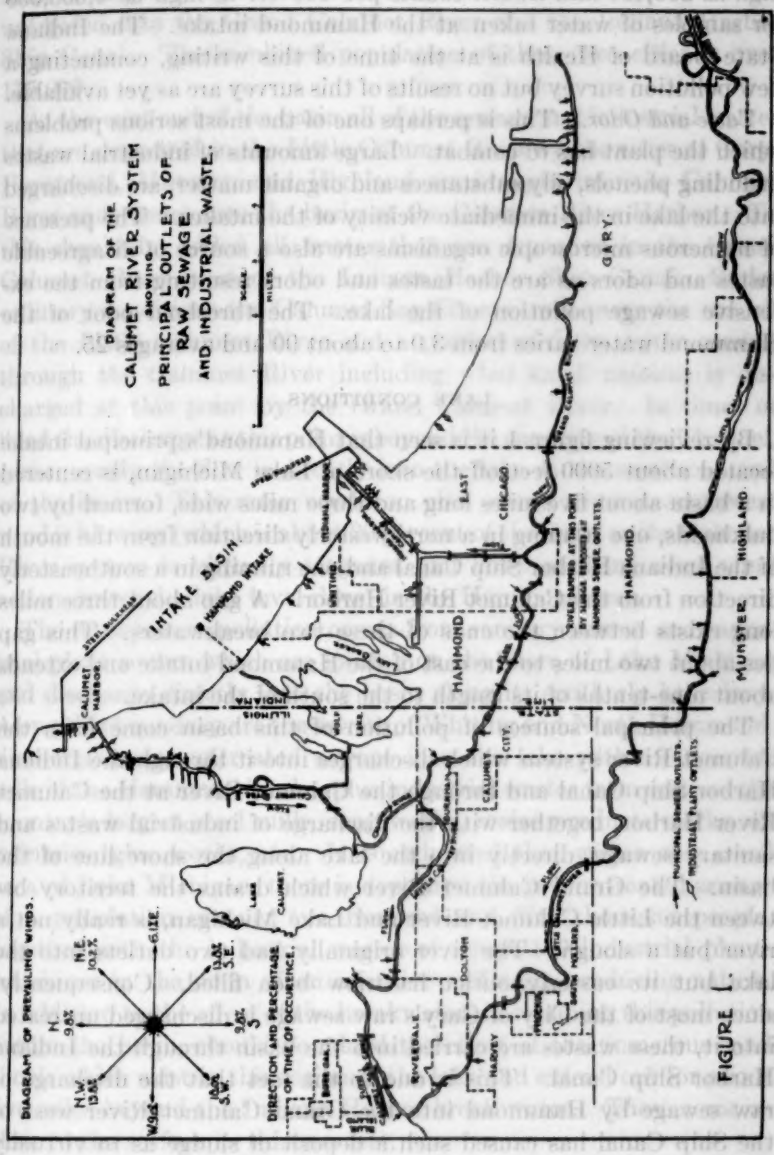


DIAGRAM OF THE
CALUMET RIVER SYSTEM
SHOWING
PRINCIPAL OUTLETS OF
RAW SEWAGE
AND INDUSTRIAL WASTE.
SCALE
MILES
INTAKE BASIN
HAMMOND INTAKE
STEEL SUNKEN
CALUMET HARBOR
ILLINOIS INDIANA STATE LINE
HAMMOND
EAST CHICAGO
GARY
HIGHLAND
MUNSTER
CALUMET CITY
DOLTON
RIVERDALE
HARVEY
LAKE
CALUMET
DIAGRAM OF PREVAILING WINDS.
DIRECTION AND PERCENTAGE OF TIME OF OCCURENCE.
N. 9.6%
N.E. 10.2%
E. 6.1%
S.E. 13.8%
S. 9.6%
S.W. 18.2%
W. 9.6%
N.W. 13.8%
PRINCIPAL SEWER OUTLETS.
INDUSTRIAL PLANT OUTLETS

FIGURE 1.

Health Service revealed bacterial counts (agar 37°C. 24 hrs.) as high as 250,000 and *E. coli* counts per 100 cc. as high as 1,000,000 for samples of water taken at the Hammond intake. The Indiana State Board of Health is at the time of this writing, conducting a new pollution survey but no results of this survey are as yet available.

Taste and Odor. This is perhaps one of the most serious problems which the plant has to combat. Large amounts of industrial wastes including phenols, oily substances and organic matter, are discharged into the lake in the immediate vicinity of the intakes. The presence of numerous microscopic organisms are also a source of disagreeable tastes and odors as are the tastes and odors resulting from the extensive sewage pollution of the lake. The threshold odor of the Hammond water varies from 3.0 to about 90 and averages 25.

LAKE CONDITIONS

By reviewing figure 1 it is seen that Hammond's principal intake located about 5000 feet off the shore of Lake Michigan, is centered in a basin about five miles long and three miles wide, formed by two bulkheads, one running in a northwesterly direction from the mouth of the Indiana Harbor Ship Canal and one running in a southeasterly direction from the Calumet River Harbor. A gap about three miles long exists between the ends of these two breakwaters. This gap lies about two miles to the east of the Hammond intake and extends about nine-tenths of its length to the south of the intake.

The principal sources of pollution of this basin come from the Calumet River system which discharges into it through the Indiana Harbor Ship Canal and through the Calumet River at the Calumet River Harbor, together with the discharge of industrial wastes and sanitary sewage, directly into the lake along the shore line of the basin. The Grand Calumet River which drains the territory between the Little Calumet River and Lake Michigan, is really not a river but a slough. The river originally had two outlets into the lake but its easterly outlet has now been filled. Consequently, since most of the City of Gary's raw sewage is discharged untreated into it, these wastes are carried into the basin through the Indiana Harbor Ship Canal. This is due to the fact that the discharge of raw sewage by Hammond into the Grand Calumet River west of the Ship Canal has caused such a deposit of sludge as to virtually dam the river at a point just west of the canal. Hammond not

only gets most of Gary's sewage to convert into drinking water but most of East Chicago's as well, as East Chicago discharges its wastes untreated into the Grand Calumet River and the Indiana Harbor Ship Canal. The combined population of these two cities is over 175,000.

At the west end of the basin all of the sewage and industrial wastes that are deposited in the Little Calumet River by the cities of Gary, Hammond, Munster, and Highland are brought into the Calumet River and thence into the basin at the Calumet River Harbor. To this should be added all wastes that are deposited in the Grand Calumet River west of the Indiana Harbor Ship Canal. Under ordinary conditions the Calumet Sag Channel will carry the run off of the Little Calumet River and a portion of Lake water coming through the Calumet River including what small amount is discharged at this point by the Grand Calumet River. In times of flood the discharge at this point is beyond the capacity of the Channel, consequently the flow is directly into the lake at the northwest end of the basin. This same condition also occurs when a southwest wind is blowing (which is about 20 percent of the time) as the Calumet River system is virtually stagnant and flows outward when wind action draws the lake level down in the Hammond area.

The most severe pollution comes from sanitary sewers and industrial plant sewers which are located on the shore of Lake Michigan and discharge directly into the basin along its southerly boundary. Along this boundary are the sewers of Whiting and North Hammond, discharging raw untreated sewage into the lake within a quarter mile of the Hammond intake, plus industrial wastes from some of the country's largest steel mills, soap works, maize products works, oil refineries, glue works, etc. It is estimated that within this small area of Lake Michigan, there is deposited the raw untreated sewage of a population of over two hundred and fifty thousand people, together with the industrial wastes of about 150 industrial plants which are in the main of an offensive and taste producing nature. In addition to the effect of the breakwaters in retaining this pollution within the basin, should be added the effect of the numerous sand shoals which exist in this region of the lake and extend out for about five miles beyond the Indiana Harbor break water. These come as close to the surface as thirteen feet.

With these sources of pollution our taste and odor problems fall

into four classes. In order of their frequency of occurrence they may be listed as follows:

1. Domestic sewage.
   a. Fresh.
   b. Partially oxidized.
2. Oil from Refinery Wastes.
3. Phenols from Steel Mill and Refinery Wastes.
4. Plant and animal organisms.

Excepting the partially oxidized sewage, this order also lists the pollutions according to the difficulty of their removal.

It would be well at this point to point out the influence of the wind directions and velocities on our problems. Obviously the only winds that can bring us clean water from the middle of the lake are the north, northeast and east winds. Our records for the ten months of our existence show that these winds prevailed 25 percent of the time. Even these winds when blowing for any length of time at a high velocity tend to aggravate instead of help the situation. For example on March 24th a storm came out of the east and we had a wind of 30 to 50 miles per hour velocity for several days. This was just after the ice had gone out and the lake was stirred up for the first time this spring. All the sewage that had been collecting in the bottom of the basin and in the meantime presumably becoming partially oxidized by the dissolved oxygen in the water, was brought to the surface. The *E. coli* count jumped from an average of 600 per 100 cc. to a range of 20,000 to 100,000 per 100 cc. and this partially oxidized sewage caused one of the most difficult odor problems we have yet had to cope with. On March 26th, an average of 515 lbs. of carbon per million gallons was used and the finished water had a residual threshold odor of 22. Thus it is seen that the best directed winds can be objectionable.

Naturally with these numerous sources of pollution and with constantly shifting winds, odors fluctuate rapidly over a wide range. This is shown by figure 2 which is a four days' record of threshold odor values of our raw water taken at random.

Soon after the beginning of operations at the plant the operators became aware of the fact that in order to abide by the policy adopted with reference to taste and odor removal, a far greater amount of carbon would be required than had originally been estimated. It was also at this time that we were besieged by the unsuccessful bidders on this particular material who attempted, by means of

results obtained from tests conducted in their laboratories, by argument, and by data of plant experiences elsewhere, to demonstrate the peculiar advantages of their particular brand of carbon for the solution of our problems. Offers of large samples of their materials for trial runs in the plant, together with technical service and advice, were made but all were declined in order to avoid obligations which might at some future date prove embarrassing. Several serious questions, however, had been raised and since the possibility of reducing operating costs by the proper selection of carbon to meet

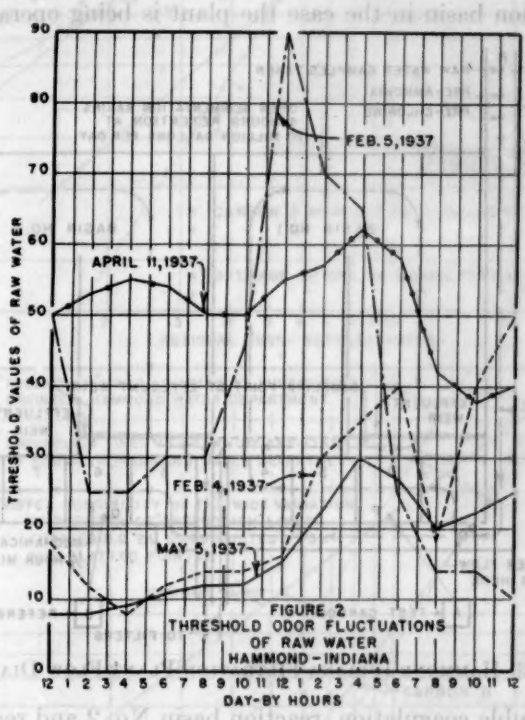


FIGURE 2
THRESHOLD ODOR FLUCTUATIONS
OF RAW WATER
HAMMOND - INDIANA

our particular problems or perhaps by the use of another material which could be substituted or used in combination with carbon, it was decided to run plant tests over relatively long periods of time on carbon and activated clays to determine if any one carbon, now on the market, or activated clay, would solve our problem more economically than it had been solved in the past. *This was the sole purpose of the tests.* This paper, however, will deal only with experiences on activated carbon, the experiences with activated clays to be made the subject of another paper.

During the design of the Hammond plant in which one of the authors was actively engaged, the possibility of plant test runs to determine the effectiveness of carbon and other chemicals was considered and provided for, as can be seen on the accompanying diagram, designated as figure 3, upon which is indicated the flow of water through the plant, the points of chemical feeds, the sampling points and the method used in making the carbon tests. Provision was also made in the design of the plant to enable the feeding of carbon into the raw water flume, the outlet conduit to the easterly sedimentation basin in the case the plant is being operated to pro-

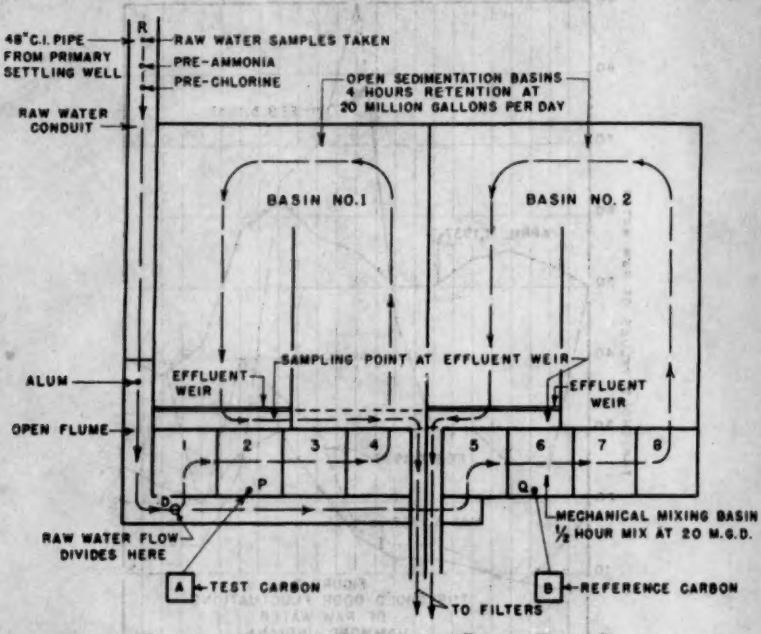


FIG. 3. HAMMOND INDIANA FILTRATION PLANT FLOW DIAGRAM

vide for double coagulation, reaction basin No. 2 and reaction basin No. 6 to provide for split feed and test runs, and in the settled water collector to provide carbon treatment of the water just as it passes onto the filters. By referring to figure 3 the method employed in making the test runs can be easily followed. Raw water is pumped into the plant by three low lift pumps which take suction in a primary settling well and discharge into a common header made up of a 48-inch cast iron pipe. Raw water samples were taken from a sampling point in this pipe ahead of all plant treatment. Pre-ammonia and

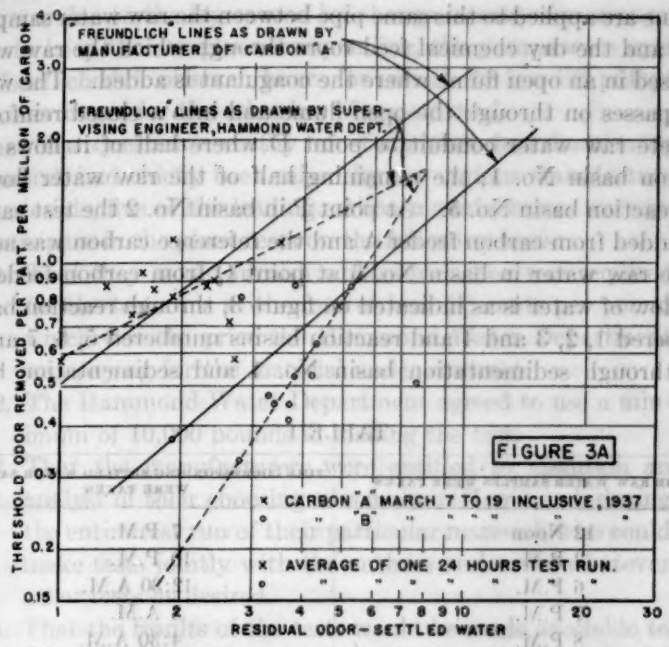

"FREUNDLICH" LINES AS DRAWN BY MANUFACTURER OF CARBON "A"
"FREUNDLICH" LINES AS DRAWN BY SUPERVISING ENGINEER, HAMMOND WATER DEPT.
THRESHOLD ODOR REMOVED PER PART PER MILLION OF CARBON
RESIDUAL ODOR—SETTLED WATER
× CARBON "A" MARCH 7 TO 19 INCLUSIVE, 1937
○ " "B" " " " " " "
× AVERAGE OF ONE 24 HOURS TEST RUN.
○ " " " " " " "

FIGURE 3A

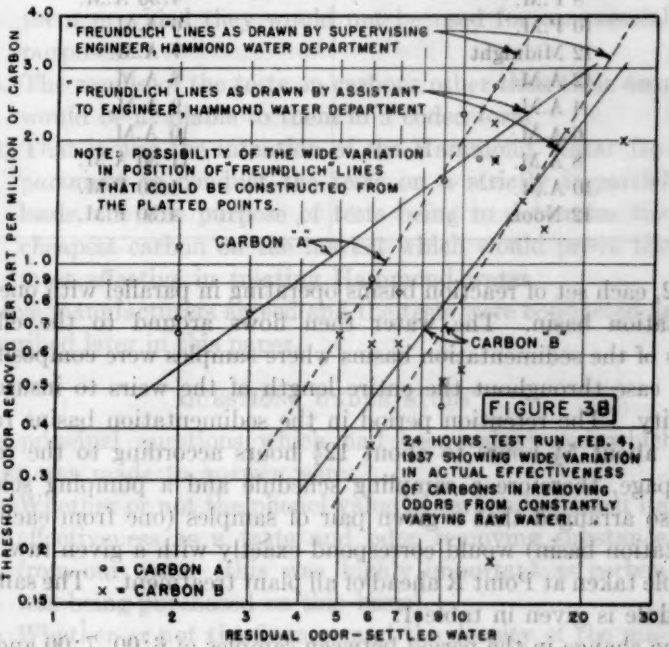

"FREUNDLICH" LINES AS DRAWN BY SUPERVISING ENGINEER, HAMMOND WATER DEPARTMENT
"FREUNDLICH" LINES AS DRAWN BY ASSISTANT TO ENGINEER, HAMMOND WATER DEPARTMENT
NOTE: POSSIBILITY OF THE WIDE VARIATION IN POSITION OF "FREUNDLICH" LINES THAT COULD BE CONSTRUCTED FROM THE PLATTED POINTS.
CARBON "A"
CARBON "B"
THRESHOLD ODOR REMOVED PER PART PER MILLION OF CARBON
RESIDUAL ODOR—SETTLED WATER
○ = CARBON A
× = CARBON B

FIGURE 3B

24 HOURS TEST RUN FEB. 4, 1937 SHOWING WIDE VARIATION IN ACTUAL EFFECTIVENESS OF CARBONS IN REMOVING ODORS FROM CONSTANTLY VARYING RAW WATER.

chlorine are applied to this same pipe between the raw water sampling point and the dry chemical feed room through which the raw water is passed in an open flume where the coagulant is added. The water then passes on through the open flume and into a closed reinforced concrete raw water conduit to point D where half of it flows into reaction basin No. 1; the remaining half of the raw water flowing into reaction basin No. 5. At point P in basin No. 2 the test carbon was added from carbon feeder A and the reference carbon was added to the raw water in basin No. 6 at point Q from carbon feeder B. The flow of water is as indicated on figure 3, through reaction basins numbered 1, 2, 3 and 4 and reaction basins numbered 5, 6, 7 and 8, and through sedimentation basin No. 1 and sedimentation basin

TABLE 1

TIME RAW WATER SAMPLES WERE TAKEN	TIME CORRESPONDING SETTLED WATER SAMPLES WERE TAKEN
12 Noon	7 P.M.
2 P.M.	10 P.M.
6 P.M.	12:30 A.M.
7 P.M.	3 A.M.
8 P.M.	4:30 A.M.
10 P.M.	6 A.M.
12 Midnight	7 A.M.
12 A.M.	8 A.M.
4 A.M.	9 A.M.
6 A.M.	10 A.M.
8 A.M.	11:30 A.M.
10 A.M.	1:30 P.M.
12 Noon	4:30 P.M.

No. 2, each set of reaction basins operating in parallel with one sedimentation basin. The water then flows around to the effluent weirs of the sedimentation basins where samples were composited in each case throughout the entire length of the weirs to insure uniformity. The retention period in the sedimentation basins ranged from about 5½ hours to about 12½ hours according to the rate of pumpage, therefore a sampling schedule and a pumping schedule was so arranged that a given pair of samples (one from each sedimentation basin) would correspond exactly with a given raw water sample taken at Point R ahead of all plant treatment. The sampling schedule is given in table 1.

The change in the period between samples of 6:00, 7:00 and 8:00

P.M. was due to the lag caused by change in rate of pumpage. In order to keep the samples corresponding, the pumps were operated on a fixed schedule of seven hours for one of the low lift pumps and seventeen hours for the other low lift pump used.

Since the questions worthy of study that had been raised at Hammond, had chiefly been raised by the various manufacturers of the materials, five of the leading carbon manufacturers were invited to participate in the plant tests on the following basis:

1. That they would furnish whatever carbon was required for the test runs at the rate of four (4) cents per pound which was the price the Hammond Water Department was paying for the material under contract.
2. The Hammond Water Department agreed to use a minimum of 10,000 pounds in making the test.
3. That the manufacturers were entitled to maintain an analyst of their choosing to remain in Hammond, during the entire test run of their particular material, who could make tests jointly with the authors and make whatever other tests he desired.
4. That the results of the tests would be made available to them provided they would not be used for commercial purposes.
5. The results of the tests on carbons other than their own would be available to them in a coded form.
6. That it was the intention of the Hammond Water Department to conduct the tests on a strictly impartial basis, the sole purpose of tests being to determine the cheapest carbon on the market which would prove the most effective in treating Hammond water.

All five manufacturers agreed and the tests were conducted as will be described later in this paper.

QUESTIONS UNDER STUDY

The principal questions which had been raised and which an attempt was made to answer were:

1. Whether or not the phenol value of carbon indicated its effectiveness as a taste and odor removing substance from our water (this was highly important as carbon was being purchased on this basis).
2. Whether or not the fineness and the density of the ma-

terial made a measurable difference in its ability to remove taste and odor.

3. Whether or not the feeding of alum, chlorine, and ammonia at points close to the point of carbon feed interfered or reduced the ability of the carbon to remove taste and odor.
4. Whether or not the carbon was selective in its taste and odor removing properties.
5. Whether or not carbon, in removing taste and odor, followed a definite law.
6. What was the speed with which the various carbons reacted.
7. Whether or not one carbon was easier to feed than another.

With this program in mind the technical representatives of the coöperating carbon companies were called in and it was agreed to run the tests in the manner described as follows:

The samples were collected at the hours designated, in quart bottles with ground glass stoppers. The bottles completely filled, were stored over night in the ice box at 32°–40°F. We had previously found that samples stored under these conditions did not materially change in odor value. The raw water samples were run without coagulation or filtering. The settled water samples were allowed to stand in the ice box until the "floc" had completely settled out and the samples were decanted as we had found no filtering medium that did not impart an odor to the water. The Baylis method (diluting sample to 265 cc. in a 530 cc. flask) of determining threshold odors, with the Baylis nose piece was used throughout. One of the coöperating chemists preferred not to use this nose piece.

This method was found to be very accurate. The coöperating chemists always checked our laboratory within one threshold odor value, and samples run at succeeding intervals of hours, days and even weeks, showed the same threshold odor values. In order to insure impartiality one chemist made up the dilutions while the other determined their odor values. This procedure was reversed on alternate pairs of samples. The chemist determining odors was not only unaware of the dilutions but was also unaware of the nature of the sample being tested.

It was intended originally to compare the carbons by plotting the threshold odor removal per p.p.m. of carbon against the residual

threshold odor of the settled water and reading off the threshold odor removal per p.p.m. to a threshold odor of three (our standard for finished water), each time evaluating the test carbon against the reference carbon. However, we found that our rapidly changing raw water forced us to change the carbon feed so often that it was impossible to maintain a fixed residual odor in the settled water. So with a variable raw water, variable carbon feeds and a variable residual threshold odor, the points so plotted were too scattered to give an acceptable line. This is illustrated by referring to figures 3A and 3B, which clearly indicate that the points taken from test runs and plotted are so scattered that it is impossible to draw any line through them that would have any meaning or would serve as a basis for evaluating the carbons in question. Freundlich's equation being inapplicable, and knowing that the odor removal per p.p.m. of carbon generally increased as the raw water threshold odor went up, it was arbitrarily decided to compare the carbons according to their relative average odor removal in each raw water range of 10 threshold odor values. Later it was found desirable to break up the 1 to 10 range into a 1 to 5 and 6 to 10 range.

The reference carbon used was so chosen because it was being used in regular plant operation after having been selected by competitive bidding and having been evaluated as having the greatest odor removal properties compared dollar per dollar with the other carbons used in the test. We felt that all carbons must be compared in terms of the greatest odor removal per dollar. The odor removal properties of the various carbons being variable and the price fixed, we believed that all of the carbons could be compared with the lowest priced one which we regularly used and then evaluated to determine whether or not our plant carbon really was the most economical for our use or whether it would be advisable to change.

Each test was scheduled to run eight days but on finding that certain variations in other chemical treatment had some effect, several days were added to measure this effect. There were naturally occurrences that interrupted the schedule, but each test covered at least 100 different raw water samples over as wide a range of odors and characteristics as is practically possible with a plant test. The four tests were spread over a period of four months and represent a total of 415 raw water samples, 830 settled water samples, about 5,000 dilutions, and about 50,000 calculations.

During the period of the test the raw water temperature range was

32°–37°F. The pH was 7.7. The pH on the settled water varied strictly with the alum feed, i.e. 0.6 g.p.g. gave a pH of 7.5, 0.8 g.p.g. gave a pH of 7.3, and 1.0 g.p.g. gave a pH of 7.1.

It was hoped these tests would reveal whatever relationship exists between the odor removal capacities of the carbons and their physical and chemical characteristics. The carbon samples for determining the physical and chemical characteristics were composited from the carbon feed machines over the period of test and the characteristic tests were run afterward.

The results of the tests are consolidated in table 2, and are reviewed as follows:

1. The last column on the right in table 2 indicates that the phenol value of the reference carbon varied considerably during the tests. (The phenol values given are the averages of the coöperating carbon companies laboratories and our own). We had not anticipated this and did not discover it until the first test was over. However, we decided to continue with this carbon as the reference carbon, leaving the relationship of phenol value to odor removal to be established by the results obtained.
2. The carbon feed used in determining the odor removal per p.p.m. of carbon was the average of the preceeding and succeeding hours of the sampling time. This gave us a progressive average and allowed for any lag in pumpage.
3. The first line of figures across the table represents the average number of threshold odor removal per p.p.m. of the test and reference carbons for each range of threshold odors of the raw water.
4. Note that, as expected, this value increased as the threshold odor of the raw water increased.
5. The second line across in the table is the reciprocal of the first. That is, the p.p.m. of the test and reference carbons required to remove one threshold odor from raw water in the given range. (Both the phenol values and the odor removal values were calculated on an "as received" basis, as the carbon feeds were set on that basis.)
6. The third line across the table is the ratio of the p.p.m. of the test and reference carbons required to remove

TABLE 2

Raw Water Threshold Odor Range

TABLE 2

Raw Water Threshold Odor Range

	1–5		6–10		11–20		21–30		31–40		41–50		51–60		61–70		71–80		81–90		91–100		PHENOL VALUES	
Carbons	C_1	R_1	C_1	R_1	C_1	R_1	C_1	R_1	C_1	R_1	C_1	R_1	C_1	R_1	C_1	R_1	C_1	R_1	C_1	R_1	C_1	R_1	C_1	R_1
Th. O Rem/ppm C	.58	.31	.93	.68	1.02	.76																	14.4	22.7
ppm C/Th. O	1.72	3.20	1.08	1.47	.98	1.32																		
Ratio	1:1.86		1:1.36		1:1.35																			
No. of Samples	28	28	40	40	33	33											Grand Average Ratio				1:1.52		1:1.57	
Carbons	C_2	R_2	C_2	R_2	C_2	R_2	C_2	R_2	C_2	R_2	C_2	R_2	C_2	R_2	C_2	R_2	C_2	R_2	C_2	R_2	C_2	R_2	C_2	R_2
Th. O Rem/ppm C	.23	.17	.53	.50	.70	.55	.82	.65	1.52	1.22													19.9	25.5
ppm C/Th. O	4.3	5.8	1.89	2.00	1.43	1.82	1.23	1.53	.66	.82														
Ratio	1:1.35		1:1.06		1:1.27		1:1.26		1:1.24															
No. of Samples	3	3	30	30	60	60	6	6	2	2							Grand Average Ratio				1:1.24		1:1.28	
Carbons	C_3	R_3	C_3	R_3	C_3	R_3	C_3	R_3	C_3	R_3	C_3	R_3	C_3	R_3	C_3	R_3	C_3	R_3	C_3	R_3	C_3	R_3	C_3	R_3
Th. O Rem/ppm C			.62	.54	1.27	1.03	1.40	.98	2.38	1.71	1.42	1.09			1.93	1.75			2.48	2.30			21.1	27.0
ppm C/Th. O			1.61	1.83	.79	.97	.72	1.02	.42	.58	.70	.92			.52	.57			.40	.44				
Ratio			1.00	1.15	1:1.23		1:1.41		1:1.38		1:1.31				1:1.10				1:1.10					
No. of Samples			29	29	59	59	12	12	4	4	2	2			1	1	Grand Average Ratio		1	1	1:1.28		1:1.28	
Carbons	C_4	R_4	C_4	R_4	C_4	R_4	C_4	R_4	C_4	R_4	C_4	R_4	C_4	R_4	C_4	R_4	C_4	R_4	C_4	R_4	C_4	R_4	C_4	R_4
Th. O Rem/ppm C					.64	.70	.73	.72	.84	.80	.88	.83	.85	.83	1.12	1.11							*23.3	23.6*
ppm C/Th. O					1.57	1.49	1.37	1.46	1.15	1.25	1.14	1.20	1.13	1.20	.89	.90								
Ratio					1:92		1:1.06		1:1.08		1:1.05		1:1.06		1:1.01									
No. of Samples					14	14	48	48	20	20	7	7	7	7	1	1	Grand Average Ratio				1:1.03		1:1.01	
Total number of Samples	31		99		166		66		34		9		7		2		0		1		0		Gt. Total 415	
Percent Distribution of Samples	7.5		23.8		40.0		15.9		8.2		2.16		1.69	.49					.26		0			

C_1, C_2, C_3, C_4,—Test Carbons.

R_1, R_2, R_3, R_4,—Reference Carbons in each test.

* Hammond Laboratory only.

one threshold odor in a given range of raw water odors. The ratios given were derived by dividing the p.p.m. required to remove one threshold odor by the reference carbon by the p.p.m. required to remove one threshold odor by the test carbon.

7. We do not believe it fair to average the p.p.m. requirements for all the raw water ranges because of the over balancing effect of a few samples in the higher ranges, but we believe it is quite fair to average the ratios of the test and reference carbons. This grand average ratio is given on the fourth line in the next to the last column of the table. In the last column on the same line is given the ratio of the phenol values of the test and reference carbons.

The striking relationship between the parts per million required to remove one threshold odor and the phenol values is believed important as this close parallel holds for all of the tests.

We do not believe it would be fair arbitrarily to evaluate a carbon on the basis of its odor removal properties and then compare it with a carbon used on a different water even in the same plant for we never know exactly when we have the same water again. The threshold odor value may be the same, the apparent or predominant characteristic may be the same, but the relative amounts and influences of the other forms of pollution present are indeterminable. For example, the water may have the odor of kerosene with a threshold odor value of 25; the kerosene odor, which is easy to remove, might predominate over an oxidized sewage odor, which is very difficult to remove, but we would have no way of proving the sewage was present. Therefore, the only fair comparisons of carbon are on the same water at the same time. (For these reasons laboratory tests can apply only to the samples tested.) So on this basis we decided to interpret each test carbon in terms of its ratio to the reference carbon in odor removal capacity. In this capacity we found each of the tests to be proportional to the phenol values of the carbons.

The fifth line in the table lists the number of samples involved in each test. The last two lines list the total number of raw water samples involved in the four tests and their percentage distribution.

The largest percentage (40 percent) of samples in any raw water range fell in the only range that occurred on all of the tests (the

11 to 20 range). Eighty percent of the samples fell between the threshold odor values of 6 and 30. Therefore the relative efficiencies of the carbons in these ranges are the most important to us.

The screen analyses of the carbons showed practically no variations. All five brands showed 98 percent (± 1.0 percent) passing the 200 mesh screen and 92 percent (± 1.0 percent) passing the 325 mesh screen. Apparently there was no relationship of their fineness to their adsorption capacities.

The bulk densities of the carbons showed some variation. There was, however, apparently little relation between the bulk densities of the various carbons and their odor removal characteristics.

Various "demonstration" or "trade" tests as set up by the various manufacturers, were run on all the carbons. These tests appeared to be designed to make some peculiarity of the particular carbon appear as an advantage. At times the advantage was in favor of the carbon showing up the best according to the "trade" test but there was no fixed relationship between these characteristics and their odor removal capacities, such as existed between their phenol values and their odor removal effectiveness.

On the running of each test, an attempt was made to determine the effect of varying the alum, chlorine and ammonia treatment. For several days the plant was run without pre-ammoniation and pre-chlorination. On these days the alum was varied as follows: 0.6 g.p.g. the first day, 0.8 g.p.g. the second day and 1.0 g.p.g. on the third day. In each case the threshold odor removal per p.p.m. of carbon was low for the 0.6 g.p.g. feed, up for the 0.8 g.p.g. feed and down again for the 1.0 g.p.g. feed. Then for several successive days the plant was run with an alum feed of 0.8 g.p.g. and with an increasing chlorine and ammonia treatment day by day. The trend of this increasing chloramine treatment was to decrease appreciably the effectiveness of the carbons. In every case both the test and reference carbons dropped proportionately. On each of the tests conducted, the trends were as just described but with rapidly fluctuating raw water and corresponding fluctuations in carbon feeds, it was hard to measure these indicated trends. However, after the completion of the four major tests, we ran a fifth test, wherein Lake Michigan coöperated with us beautifully. The raw water varied only from 11.0 to 16.0 in threshold odor value and our carbon feeds were equally constant. The residual odors on the settled water samples were also constant. Therefore, our only

varied factor was the chemical feed. The effect of varying the alum feed is shown in figure 4. The effects of varying the chlorine and ammonia feeds are shown in figure 5. Each break in the line on these charts represents one day's run of 13 samples of water.

We have no proven explanation of why we get a peak absorption at 0.8 g.p.g. alum feed. A plausible theory is: that at 0.6 g.p.g. there is insufficient alum floc to remove any odor of itself and the full load is falling on the carbon. At the 0.8 g.p.g. feed there is enough "floc" to remove part of the odor which we have arbitrarily credited to the carbon; and at 1.0 g.p.g. alum feed, the floc is beginning to seal off the carbon particles before they have completed their adsorption function. This is, however, only speculation.

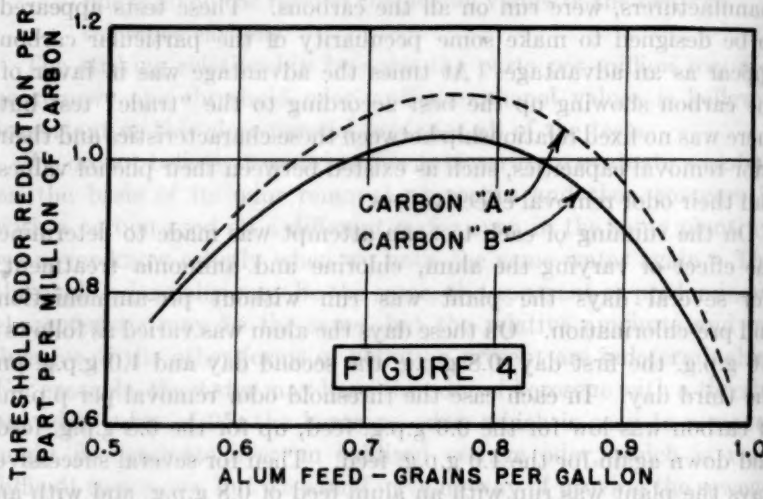
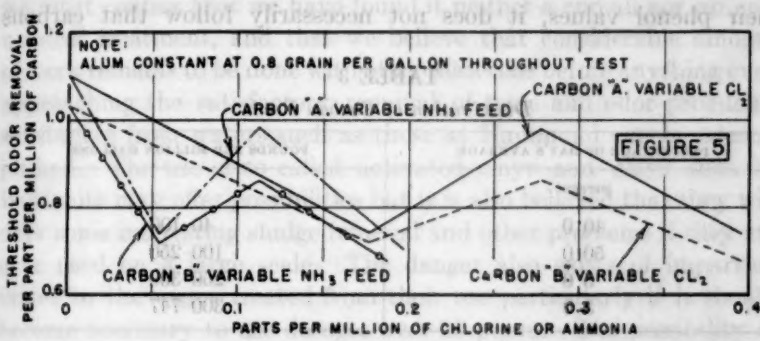


FIGURE 4

We have no theory to offer as to why increasing chloramine treatment interferes with the taste and odor removal but evidence at Hammond indicates that such is the case as can be seen by referring to figure 5. This leaves us in a difficult situation as we are unable, because of our high bacterial pollution, to omit pre-chlorination and pre-ammoniation entirely although it appears desirable—as the carbons were most effective without pre-treatment. We intended to keep the chlorine ammonia ratio constant at 2 to 1 during the tests but at certain times when our pre-chlorine requirements dropped as low as 0.2 p.p.m. the ammonia feed was hard to regulate and the actual ratio fed was 3 to 1 instead of 2 to 1. The results of this feed are indicated by the first breaks in the lines of figure 5. It is entirely

possible that the chloramines formed at this ratio were being adsorbed by the carbon, resulting in a decrease in the effectiveness of the carbon in the removal of odors in the water itself. When chlorine was fed at the rate of 0.3 p.p.m. with a ratio of 2 to 1 to the ammonia, the effectiveness of the carbons was increased but not back to the point of effectiveness when no chlorine or ammonia was fed. Again note that when the pre-chlorine feed was increased to 0.4 p.p.m. with the same 2 to 1 ratio with ammonia, the effectiveness of the carbons again fell off. The only conclusions we can draw from these results are that of these particular concentrations and ratios of pre-chlorine and ammonia treatment for Hammond water, 0.3 p.p.m. chlorine and 0.15 p.p.m. ammonia, seem to work best with our carbon treatment. It may be added that in no case did the chloramine treatment assist the carbons in any way in odor removal



which is so far as we know, contrary to popular belief. The suggestion that pre-chlorination alone be used is impossible at Hammond due to the great possibility of the formation of chloro-phenols in the raw water which would probably add an even greater burden on the carbon than is now imposed on it.

We attempted to break down the data according to the variation in the apparent characteristics of the raw water but we have found just as much variation within a given characteristic as between the different characteristics. We did not find any conclusive proof of the comparative selectivity of any particular brand of carbon. None of the carbons showed an affinity for chloramines in the higher concentrations. Only one carbon showed a tendency to adsorb chlorine alone which seems to be contrary to popular opinion.

Samples were taken at regular intervals from the exit point of the reaction basins for the purpose of comparing the speed of adsorption

of the carbons in our plant. In every case approximately sixty percent of the total odor ultimately removed, had been removed at the end of the mixing period. So we can conclude, that in our plant all fine carbons absorb rapidly and at relatively the same rate.

As to the feeding characteristics we are now able, after much experimentation, to feed all brands of carbon uniformly regardless of their bulk density. We do, however, wish to point out that since it does not follow that a light carbon is more active than a heavier one, it was necessary for us to make changes in our machines so as to enable us to meet our requirements when we were using the lighter carbons. In table 3 is given a rough distribution of our carbon feeds over a ten months period of operation.

In conclusion we would add that while we believe that the best known method of evaluating carbons at this time is on the basis of their phenol values, it does not necessarily follow that carbons

TABLE 3

Distribution of Carbon Feeds

PERCENTAGE OF DAY'S AVERAGE	POUNDS PER MILLION GALLONS
percent	
40.0	40–100
50.0	100–250
5.0	250–300
5.0	300–747

adsorb other substances in the same manner, nor that this method of evaluation is an infallible one.

We wish to caution the reader, however, that while we did not find it practical to evaluate carbons by means of the Freundlich adsorption equation, we have found no occasion thus far to be in disagreement with such a method provided that the quality of the water being treated remains unchanged. In view of the fact that the quality of the raw water during the tests varied over a wide range, it was practically impossible, as previously stated, to derive any form of equation, after Freundlich, which could be unquestionably applied to predict the possible effectiveness of the various carbons used during the tests. It should also be borne in mind that while carbons readily adsorb phenols and that while this seems to be a practical basis upon which to evaluate carbons used for water works purposes, there is no positive proof that carbons will remove the

complex organic taste and odor producing compounds which are daily required to be removed from our raw water, in same manner that phenols are removed; namely by adsorption. There still exists considerable doubt in our minds as to the ability of carbons even materially to reduce the effect of some of the taste and odor producing substances encountered in the Hammond raw water. On several memorable occasions when the threshold odor of the water was about 20 to 25 and the carbon feed was set at 25 to 30 p.p.m. we consistently got threshold odors of 21 and 22 in our finished water. We of course cleared up the situation in due course of time by continually increasing the carbon feed but the truth of the matter may be that the raw water cleared of the particular substance that was causing the trouble. There has been considerable activity of late relative to the use of carbon in the orderly treatment of water but we must confess that we have found it neither a cureall nor an economical treatment, and that we believe that considerable amount of work remains to be done with other materials before anything even approaching the satisfactory removal of taste and odor producing substances from waters such as those at Hammond can be accomplished. The use of so called activated clays and clays such as Bentonite may offer possibilities but it is also believed that they will offer some interesting sludge removal and other problems if they are ever used on a large scale. The danger also exists of imparting tastes to the water treated from their use particularly if it should become necessary to use dosages over 20 p.p.m. The possibility of setting up colloidal suspensions in order to displace the minute taste and odor producing substances by other materials that could later be readily coagulated, may be a method of attacking the problem but it would certainly present grave dangers if carried on on a large scale in hands other than the most competent. We have been amused at times by large numbers of articles regularly appearing in the current literature whereby such and such town solved all of its taste and odor problems by feeding carbon in ranges of from 2 to 3 p.p.m. According to Hammond standards this water was already perfect as we have our hands full trying to maintain a threshold odor of 3 in our finished water.

SUMMARY

1. The tests seem to indicate that on the Hammond water, the phenol adsorption test is the best known method to date of evaluating carbon for the purposes of taste and odor removal.

2. There is no fixed relationship between the physical properties of activated carbon and its capacity to remove taste and odors, other than the relationship that is reflected in the phenol adsorption test.

3. (a) The best taste and odor removal was obtained at 0.8 g.p.g. alum feed.

(b) Increasing the chloramine treatment decreased the effectiveness of the carbon. In every case the chloramine treatment did not lighten the load on the carbon but actually seemed to interfere with the action of the carbon.

4. The carbons tested, as compared with the reference carbon, showed no tendency to be selective toward the different taste and odor characteristics.

5. The capacities of the carbons to remove tastes and odors increased as the threshold odor value of the raw water increased, which might indicate agreement with the Freundlich adsorption equation in this particular. The ratio of the test carbons capacity for taste and odor removal to that of the reference carbon, was in every case, very close to the ratio of their phenol values.

6. The percentage of total odor removed, that had been adsorbed at the end of the mixing period, was roughly the same for all carbons.

7. The carbons having the highest bulk densities appeared to be the easiest to feed. However, feeding characteristics were not directly related to the bulk densities and we did not consider this item important as we were able after considerable experimentation as heretofore stated, to feed all brands of carbon successfully.

ACKNOWLEDGMENTS

We wish to express our appreciation to those who coöperated with us in the performance of the tests. Without their help the tremendous volume of work involved would have been insurmountable. Their pertinent suggestions eliminated many of the problems encountered. Those to whom we are indebted for their assistance are: our operating staff, headed by Mr. Lloyd E. Bussert and Mr. Michael Papach, Mr. Henry Laughlin of Industrial Chemical Sales Co., Mr. W. A. Helbig of the Darco Corporation, Mr. R. W. Rowley of the Cliffs-Dow Chemical Co., and Mr. Henry Salomon, Jr. of the American Norit Co., Mr. T. Tuinman (for the preparation of the charts and drawings included herein) and Miss M. Mitchell (for typing the paper).

Discussion by MATHEW M. BRAIDECH: In exercising the valued prerogative of my committee chairmanship,* I wish to undertake the discussion of the presented paper both as to its merits and possible reaction on the part of the inquiring reader and the potential user of activated carbon.

The intelligent approach to and method of conducting this plant scale test, as well as the presentation of the findings, is worthy of a great deal of commendation on the part of everyone interested. It is hoped that many other water works operators will be encouraged to follow the author's example by making similar observations and reports of their cases available to the water works field. Such papers and periodic reports on various plant experiences can be of immeasurable value to any committee efforts that may be existent at the time.

The authors do well to warn against the breach of good ethics in commercializing the experiences and findings at Hammond. Overzealous promulgation of experiences at any one plant quite often results in the violation of good faith on the part of the average water works operator, to the extent that further coöperation with and from other interested manufacturers is not so readily available the next time such is desired.

From a standpoint of general criticism, it might be said that the paper emphasizes disproportionately, with some contradiction, certain features of the work and the results obtained. In the first place, the authors point out that they were not able to find any close relationship between the Threshold Odor Test and the Freundlich equation, but attach great weight to the relationship of the carbon value of the phenol test. It seems rather elementary to expect that, if the phenol test parallels the Threshold Odor Test, and if the phenol test follows the Freundlich equation, that the Threshold Odor Test should do likewise. Equal importance should be given to both items rather than to merely use one to substantiate and validate the other. Considering the rapid fluctuations of the character of the raw water, not to say anything about the variations in carbon dosage, it would hardly be expected that results falling on the Freundlich curve would be obtained even under the closest surveillance.

The paper seems to indicate considerable opposition to the Threshold Odor Test, and yet reports remarkably close agreement between

* Asst. Professor of Chemical Engineering, Case School of Applied Science, University Circle, Cleveland, Ohio and Chairman, A. W. W. A. Committee on Specifications and Tests for Activated Carbon.

the five coöperating chemists using the test, always checking their laboratory (the authors) within one Threshold Odor Value. In every case where an effort has been made to establish the value of the phenol test, it has been on the basis of a parallel to the Threshold Test. It is hard to see how it could be based on anything else. The striking relationship that is pointed out in the grand average ratios on table No. 2, between the parts per million of carbon required to remove one threshold odor value and the corresponding phenol values of the different carbons tested, tends to reverse any opposition to the direct odor testing procedure.

The one real and definite objection to the Threshold Odor Test is, of course, the fact that tastes and odors vary so greatly and make it difficult to use as a method of insuring delivery of a consistent quality of activated carbon. Of course, the phenol test to this extent does fit in very well, that is, if you place a bid on the basis of a definite sample, the phenol test makes it possible to make sure that you have future deliveries of the same type of material, and, further than that, it helps to define, to a degree, a water purification grade of carbon; thereby eliminating the introduction of inferior and unsuitable grades of carbon. On the other hand, being such a yardstick, it does not assume that the carbons will adsorb all the complex organic taste and odor producing compounds in the same manner. As a matter of fact, specific instances have been reported where the Threshold Odor Test demonstrated as much as 30 percent difference in various types of carbons on a particular water, even though the phenol values of carbons in question were practically the same. And again, in three municipalities the Threshold Odor Test showed the effectiveness of a series of different carbons to be in the reverse order of the phenol values determined by the usual recommended method. Such reports seem to indicate limitations of the phenol test, due to the fact that it does not take into account that the various tastes and odors encountered vary widely in their quality as well as in their respective intensities. The simple thought of the fact that decomposing vegetation and plankton organisms give rise to a complicated agglomeration of possibly several hundred unindentifiable organic compounds, is sufficient to recall the old saying, so familiar to most water works mem, "Every Tub on Its Own Bottom." It is understood that the predominating type of pollution at Hammond was almost entirely phenolic in character, then in this particular case the Phenol Test may be considered as sufficiently dependable to give predictable

indications of the relative efficiencies of different carbons that might be expected in actual operation. However, in plants where taste and odor difficulties are of an organic nature, the Phenol Test should be supplemented by the Threshold Odor Test; not only as a matter of verification, but also to enable the operator to run routine tests on the quality of both his raw and finished water and making it possible for him to know *when* to add activated carbon, and, at least roughly, *how much*, to add.

One of the greatest dangers in giving an all-round unqualified indorsement to the Phenol Test alone, at this time, lies in the fact that it would form a narrow channel through which future progress in activated carbon treatment must travel. This, of course, would be entirely satisfactory if the relationship of the Phenol Test to taste and odor removal is universally true. Otherwise it can very easily lead to the condition where the carbon manufacturer by making a carbon having a phenol value of 10 could feel justified in charging almost twice the price of 20 phenol value carbon, and the consumer would be justified in buying on this basis. The net result could easily lead to penalizing both the manufacturer and the consumer by making activated carbon expensive in terms of its efficiency for the removal of tastes and odors. The carbon committee is quite cognizant of this fact and has therefore tentatively recommended the Threshold Odor Test as provisional supplement to the recommended Phenol Test: From all present indications, the Threshold Odor procedure is capable of being developed into a workable common sense procedure, and the committee trusts that a favorable reception and an earnest trial will be afforded to this test technique.

The committee is inclined to disagree with the authors in respect to the matter of payment for any retesting of disputed samples. To make equitable terms of settlement, the party in error should be required to assume the cost of retests. Opinions in regard to other test items are in agreement with the committee recommendations.

In general summation, the severe nature of the Hammond problem is not readily apparent unless a careful study of the report is made. The permutations and combinations of the reported contaminating agents (domestic sewage, oil from refinery wastes, phenols from steel mill and refinery wastes, and seasonal plant and animal organisms), which respond in different proportions with the shifting of winds, causes the situation to appear as a veritable haven for tastes and odors. As a matter of possible fact, the condition that Hammond may encounter from now on may differ radically from what it has

experienced during the interim of this work. The information derived from this short period of operation may be entirely changed by their experiences within the next year or the years to follow. In fact it would be extremely unlikely if this were not the case. I am certain that most persons feel that the information given is interesting as a study of one particular set of conditions—similar to the Chester, Pa. experiences reported by Geo. D. Norcom in 1931—and that it should be limited to that particular set-up and conditions. The water works chemists and operators should therefore be careful not to draw any conclusions as to their own problems from reading this paper.

In nearing conclusion, with a problem so difficult, it is questionable whether or not the irregularities of the raw water are sufficiently ironed out by the usual preliminary treatment and that therefore more is required of the activated carbon that it should be asked to do. Raw waters of this type generally demand double stage treatment rather than the standard single stage treatment. The use of granular carbon beds, affording sufficient potential and reserve adsorptive power to meet all emergencies, similar to Oshkosh and Bay City design, might be a step in a helpful direction. In the ultimate consideration, an extended intake beyond the bulkheaded and partially enclosed bay might be the answer to this problem should it continue to persist.

In closing, there has been no intent to detract from the excellence of this report. The principal object of these notations has been to amplify a number of points of concern to the carbon committee and to prevent the casual reader from applying the conclusions of the authors too broadly. The discussor reiterates his admiration for the competent way the work was conducted under such extreme and adverse conditions, and certainly hopes that the water works fraternity will welcome the report as a valuable contribution to its existing fund of knowledge on the taste and odor control problem.

Authors' closing comments. We appreciate the careful study Mr. Braidech has given our paper and generous tone of his discussion. We do, however, believe he has received some erroneous impressions of the points of view we intended to present, therefore we take this means to clarify our position.

In reviewing Mr. Braidech's discussion, we note that he expresses the opinion that an overzealous declaration of experiences at a particular water works plant often results in a violation of good faith

on the part of the operators to the extent that interested manufacturers are reluctant to extend further cooperation to the operators when they attempt to extend their studies in the future. While this may be true, we must confess that we have seen no evidence of it at Hammond. The prime reason that these men were invited to the plant during the tests was to prove to them that we were not indulging in a Roman holiday but were attempting to carry out our tests on a strictly impartial basis. They had full opportunity to criticize our methods, make suggestions, or any tests that they desired, to prove their claims regarding the activity of their carbon. We believe that we succeeded in demonstrating our fairness to everyones satisfaction. We would caution Mr. Braidech that the prime function of a manufacturer is to sell his product and that major improvements in quality are generally brought about by competition and demand. We as consumers and purchasers are naturally cautious particularly in view of the fact that our carbon costs run better than $25,000 per year. In view of the fact that we are acting in an advisory capacity to a Board of Trustees, we naturally feel our responsibility even more than if we were spending our own money. We believe that our insistence relative to the quality of carbon used at Hammond has not only been successful in enabling us to buy better carbon at a lower price but has also relieved us of the trouble of having to deal with companies who make exaggerated claims for their material which they cannot hope to live up to. As evidence of this we wish to present the bids we received last year on carbon as compared to the bids we received this year. We received fewer bids this year but no one offered a bid this year that couldn't make the grade whereas it appeared that several had the year previous.

Bids Received by Hammond Water Department on Activated Carbon

1936				1937			
Bidder	Price per lb. carload lots	Phenol value	Evaluated bid price on phenol 20	Bidder	Price per lb. carload lots	Phenol value	Evaluated bid price on phenol 20
A	$0.0495	20	$0.0495	A	—	—	—
B	0.0511	16	0.04088	B	$0.0481	15	$0.036085
C	0.0495	20	0.0495	C*	0.041	17	0.03485
C	0.047	25	0.05875				
C	0.04325	30	0.0648				
D*	0.04	20	0.040	D	—	—	—
				E	0.425	17	0.036125

* Award made.

No data are offered in our report showing a lack of correlation between the Threshold Odor Test and Freundlich's Equation. It is merely demonstrated in figures 3A and 3B that when the odor removal expressed in threshold odors removed per p.p.m. of carbon is plotted against the residual odor of the finished water, according to Freundlich's equation no line could be drawn that would be representative of the data plotted. This is probably caused by the varying character of the raw water each point plotted falling on a particular curve corresponding to a particular type of odor but since we are unable to hold the odor constant we naturally get scattered points. In order for us to get a complete picture of what a carbon would do we used the arithmetical averages given in Table 2. In each case the reference carbon is compared with the test carbon on the basis of the average parts per million of carbon required to remove one threshold odor on the given raw water range. This value is the reciprocal of the threshold odors removed per p.p.m. of carbon which was derived from the differences in the threshold odors of the raw and treated water (determined by the threshold odor test) divided by the average p.p.m. of carbon used. We are very much at a loss to understand Mr. Braidech's statement that we were not able to find any close relationship between the Threshold Odor Test and the Freundlich Equation. We realize the relationship that exists between the Threshold Odor Test, the Phenol Value of a carbon and Freundlich's Equation. The adsorption of phenol by carbon closely follows Freundlich's Equation and all of the equations which we plotted were derived by making use of the Threshold Odor Test. While we believe that the Freundlich Equation is perhaps the best known attempt to express the adsorption properties of a substance, it is still far from being satisfactory and especially in cases such as instances that have occurred during the Hammond tests when evidence seemed to point to the fact that no adsorption was taking place. It would perhaps be possible to evaluate equitably various carbons by means of the Freundlich Equation applied to adsorption of phenol by carbon but this would only be another means of restating the phenol value of the carbons in question.

We have not expressed opposition in our paper to the Threshold Odor Test as a means of evaluating carbons. The Threshold Odor Test was used during the Hammond experiments to determine the amount of odor removed by the test and reference carbons. We found this odor removal as reported to be in the same ratio as the

phenol values of the carbons and because of this fact we stressed the phenol test as a yardstick to be used in the *purchase* of carbons. We are not opposed to the Threshold Odor Test and find it very valuable as an aid in the operation of our plant. We are, however, opposed to the use of the threshold odor test used alone as a means of evaluating carbons when we are considering purchases. We believe that the phenol value test is a good way to measure the activity of carbons and that this test can be supplemented with the threshold odor test so as to determine the actual odor removal capacity of the carbon on the particular water in question. We do not, however, believe that we can, when we are considering the purchase of a years supply of carbon, make use of the Threshold Odor Test in a practical way to assist us in making a selection of the carbons offered us. An attempt to award a contract on such a basis would be farcical with every manufacturer's representative attempting to outsmell his competitors. Some manufacturers have, from time to time, contended to us that the threshold odor test was the only reliable way to buy carbon. We on the other hand, have contended that while the test is a valuable aid, it cannot be practically used in the purchase of carbons as the human equation plays too strong a part in the test which would always leave doubt in the mind of the awarding body and which would in a short time cause dissatisfaction to everyone concerned except the successful bidder. Any manufacturer who advocates the purchase of carbons solely on such a basis depends more on the personality of his representatives to sell his product than upon the quality of his carbon.

There are four principal reasons why we believe carbons should be evaluated and purchased on the basis of the phenol test. These are given as follows:

1. In the phenol value test the concentrations of residual phenol is measured against a definite known quantity of phenol which is a pure reproducible chemical compound. In the threshold odor test the residual odor is not compared with a definite concentration of odor producing material of known composition and until an equally definite odor standard can be established, the threshold odor test must remain supplementary to the phenol value test.

2. The threshold odor test for reasons given above, cannot be expressed in terms sufficiently specific that the test may be written into a carbon contract such as outlined in our paper.

3. The quality of our own water is so variable that a threshold

odor test on it at the time of purchase of the carbon would not be indicative of the performance of that carbon during its period of use particularly when this period is a year as we set it up in our contracts.

4. Carbon is used in the treatment of water on the theory that it will adsorb odors, therefore, since it is a proven fact that carbon will adsorb phenol and that this adsorption closely parallels Freundlich's adsorption equation, it must follow that the phenol value of a carbon is a measure of its activity and ability to adsorb odor when it acts by adsorption.

Mr. Braidech states that specific instances have been reported where the Threshold Odor Test demonstrated as much as 30 per cent difference in various types of carbon in a particular water even though the phenol value of the carbons in question were practically the same. We question the completeness of these reports. Carbons are fed to waters on the theory that they will remove tastes and odors by adsorption and since the phenol value of a carbon is a measure of its adsorption property, how then does one carbon having an identical phenol value with that of another carbon, remove more odor than the second carbon when both carbons are acting by adsorption. The answer might be that the first carbon is more selective to the particular odor than the second carbon. This, however, we have never been able to demonstrate. Carbons compared with each other may and will remove odors in varying degrees according to their activity but they are not selective. Very little is known about the action of carbons in water particularly because of the fact that it is impossible to determine accurately what is in the water that is causing odor. When attempts are being made to remove odor caused by unknown complex organic compounds, it is rather difficult to ascertain whether or not the carbon is adsorbing the odors set up and to what degree this adsorption is taking place. Carbons do, however, act about the same on the same type of odor in direct proportion to their respective adsorption properties.

Mr. Braidech understands from our paper that the predominating type of pollution at Hammond is phenolic in character. While phenols in our raw water are a major source of trouble to us, our main difficulties are caused by domestic sewage pollution of our source of supply. Mr. Braidech further states that where odor difficulties are caused by organic compounds that the phenol test should be supplemented by the Threshold Odor Test to enable the operators to know *when* and *how much* carbon to add. We are certainly at a

loss to understand how Mr. Braidech believes we control our carbon dosages. We know of no better means of feeding carbon than by the Threshold Odor Test and consider it one of the most important of our routine tests. Our operators are required to make odor tests on raw and finished water every two hours day and night, year in and year out. Furthermore our operators are given very careful and detailed instructions relative to the amounts of carbon to feed based on threshold odor of the water and the phenol value of the carbon and in the event any slip ups occur we have means of checking back to almost the exact time when it happened. The fact that we are able to check up and can place the blame for any bad water that might get by, on a specific operator, keeps our men alert to an astonishing degree in this particular.

Mr. Braidech believes there is some danger in endorsing the phenol test as it might provide a channel in which the future progress of activated carbon might lie. We, on the contrary, believe that this is a step in the right direction as the Threshold Odor Test for reasons previously explained, can never do more than serve as a check or guide as to the activity of carbon. We point out that while there is a relationship between the Phenol Test and the Threshold Odor Test, that it is not practical to check the activity of a particular brand of carbon against another one when you are dealing with raw waters that are constantly varying. We disagree with Mr. Braidech and firmly believe that a manufacturer is fully justified in practically doubling the price of a carbon when he cuts the phenol value of his carbon in two. When this is done a carbon has been made twice as active and according to our experiences will remove a proportionately greater amount of taste and odor, therefore, it is worth twice as much and really worth more than twice as much to the water works operator as he has to handle less of it and uses less machinery to feed it. No one is penalized when a better product is made unless the manufacturing costs are increased beyond proportion to the increase in quality. If such a practice unduly makes the cost of activated carbon treatment in terms of its efficiency more expensive as Mr. Braidech believes, he can always resort to buying cheaper carbons having higher phenol values. We, on the contrary, will continue to purchase carbons having the lowest phenol value per dollar. Mr. Braidech believes that the Threshold Odor Test is capable of being developed into a common sense procedure. We believe it has already been developed into a common sense procedure and use it regularly

in our plant operation. We do not, however, believe that it can be developed into a common sense procedure for *buying* carbon.

If Mr. Braidech is willing to purchase thousands of dollars worth of carbon per year on bases of such a test, he is taking a great rish of entering into a poor bargain for obvious reasons. The odor test is impractical for the purchase of carbons and will always be a source of argument and may even lead to chicanery on the part of disreputable manufacturers. Let Mr. Braidech check the percentage of water works who buy chemicals on rigid specifications. Let him also bear in mind that the average water works is not blessed or shall we say cursed with a competent technical staff and that some certain manufacturers will sell a water works operator charcoal for activated carbon if they can get away with it. What more common sense procedure is there than having the manufacturer stamp the phenol value of his carbon *on the bag* and then making him guarantee it. Remember the Threshold Odor Test and the phenol value of a carbon are distinctly related and any procedure such as outlined above is good protection to the small water works operator who may not even know what the Threshold Odor Test and phenol value of a carbon is but who can quickly have a private laboratory ascertain the phenol value of the carbon he is buying. It may be argued that carbons could be similarly evaluated by means of the Threshold Odor Test but a moment's reflection will bring to mind the difficulties that would arise by the use of such a method when dealing with varying raw waters.

We note that the committee disagrees with our manner of payment for retesting disputed samples. We might add that as a rule the phenol values of carbons are not carefully checked by manufacturers making shipment therefore we naturally go to the expense of checking each shipment. Due to the possibility of error we always rerun our tests a second time to be sure of our ground before requesting a retest. In the short time the Hammond plant has been operating, we have tested about thirty five cars of carbon and in the case of re-tests our batting average to date is 1000. We believe this is a very minor point which does not involve great expense, therefore, we are not inclined to quibble over it.

We can hardly take kindly to Mr. Braidech's statement that other water works operators should be careful in drawing conclusions from our tests as we know of no other actual tests as extensive as those made at Hammond over such a wide range of actual operating conditions. We believe we encounter more different types of odor

in one day than the average water works operator will ever encounter. There may be better proving grounds for carbon but they are most certainly very few in number. We do not have any specific set of conditions at Hammond but widely varying conditions covering practically every type of odor and if our experiences are such that they cannot at least serve as a guide for other operators, we are most certainly at a loss to determine just what sort of information another operator would require in his set up to attempt to combat the troubles he may be having at his plant. Raw water conditions are constantly changing and may be entirely different a year from now but we most emphatically state that these changing lake conditions are taking place in a direction causing our raw water to become worse instead of improved.

We note Mr. Braidech's rather general remarks that the solution of our problem will probably ultimately lead in the direction of carbon filters or an intake extension. We no doubt could probably ease conditions a great deal by following such a suggestion but we most certainly as Engineers could never justify such an expenditure. For Mr. Braidech's further information, we have already checked both of these points very carefully resulting in a demonstration that the yearly interest on the investment required to follow either of the above suggestions, will yearly buy many times the amount of activated carbon we are now using. This, however, is neither here nor there in regard to what carbon can do. The only practical solution to our problem is to clean up Lake Michigan. We have emphatically asserted this in the past and will continue to assert it in the future. Conditions are certainly a long way from ideal when it is suggested that a water works make a large expenditure in order to make the diluted sewage of 300,000 people fit for the consumption of 70,000 other people. We might add that when we say fit for consumption we not only mean a water bacteriologically safe but also one that is palatable and sparkling, for in our opinion a water is not fit to drink unless it is clear and palatable regardless of how safe it may be. The answer to our particular problem is as we have already pointed out, sewage disposal and unless this is soon forthcoming we may not be able to continue to carry the load. Without sewage disposal it would be necessary for us to keep on extending our intakes to get out of the ever increasing zone of pollution. Such a method to say the least is hardly a practical solution of our problem.

In conclusion the authors express their appreciation to Mr. Braidech for his valuable suggestions and comments.

ABSTRACTS OF WATER WORKS LITERATURE

Key: JOURNAL of the American Water Works Association, **29**: 10 (1937). The figure **29** refers to the volume, 10 to the page of the JOURNAL and (1937) to the year of issue. If volumes of a publication are not paged consecutively but by issues, the figures **29**: 1; 10 (1937) indicate—volume 29, number 1, page 10 and 1937 as the year of issue. Initials *W. P. R.* signify that abstract is reproduced, by permission, from *Water Pollution Reports (British)*.

WATER SUPPLY—GENERAL

Water Project Ends "4-Inch Baths." MARJORIE B. RIDDLE. Am. City, **57**: 7; 71 (1937). The construction of Lake Kahola Dam, 23 miles northwest of Emporia, Kansas makes available a 2½ years' supply of water and refutes the reputation of city for "4-inch baths." A Public Works Administration project, job involved building an earth filled embankment with puddled-clay core over a length of 2000 feet and with a width of 400 feet. 31 feet of the lake side of the dam is riprapped. The maximum dam height is 68 feet and the maximum depth of water, 57 feet. Total lake acreage is 404. The lake is already a haven for outdoor enthusiasts.—*Arthur P. Miller.*

Distilled and Sterile Water Supply in a London Hospital. ANON. Engineer, **163**: 302 (1937). Describes a plant for producing distilled and sterile water in use at University College Hospital, London. The plant is situated on the roof and heat for the evaporator is supplied by steam at a pressure of about 20 lb. per sq. in. from boilers in the basement. A breathing device of heated cotton wool provides sterile air above the water in the storage tank. The water is distributed to various parts of the hospital by stainless steel pipes which resist the action of hot distilled water. Stainless steel is also used for the condensing surfaces, storage tank, cooling cylinders and draw-off taps.—*W. P. R.*

London Water Supply. The Surveyor, **91**: 661 (1937). ANON. During the past three years 78,566 additional services and 457 miles of new mains have been added to the Metropolitan Water Board's system. Three new reservoirs will be constructed to add 11.58 billion gallons to the Board's storage. Millions of pounds have been saved by establishing the Thames as the main source of supply, first by storage, secondly by filtration, and lastly by chemical treatment.—*H. E. Babbitt.*

Water Supply in Scottish Rural Areas. Need for Schemes on Comprehensive Lines. ANON. The Surveyor, **91**: 534 (1937). A summary of an address by T. F. Henderson, city engineer of Aberdeen. For small burghs under 10,000 and the rural areas, the water supply, in many instances, apart from being insufficient for public health purposes, is of doubtful quality, particularly that

supplied to schools and villages. The importance of the subject has been brought to the attention of the Secretary of State for Scotland and to the Scottish members of Parliament. Water supplies should be developed on natural lines as nature does not recognize such artificial boundaries as now divide one parish from another. Two million people now living in Scottish rural areas have a right to demand a clean and wholesome supply of water.—*H. E. Babbitt.*

Institution of Water Engineers. Papers Presented at Summer Meeting at Portsmouth. The Surveyor, 91: 781, 814 (1937). *Indian Waterworks Problems*, by C. W. Cassé. By far the most important factor in the development of Indian waterworks is the elimination of waste. Various schemes included "decentralized storage," the use of meters, and "waste not" taps. Meters were most effective in preventing waste. In Ceylon there is no prejudice against accepting waterworks proposals except on grounds of finance and taxation. The general standard of supply was 20 gallons per day per capita. Consumption in Colombo is 45 gal. per day per capita. Waste in Ceylon is minimized by the use of fittings of high standard, sealed at the water works office after hydraulic test. *Water Boosting* by D. H. B. Reynolds. The high-pressure zone at Folkestone is supplied by a booster station aided by both public and private storage tanks on the distribution system. Boosting at Folkestone begins about 7.45 a.m. although the peak demand occurs about 9 a.m. Automatic control of boosting at Portsbridge effects economy only through station attendant's wages. A saving of £25,000 was made by the installation of a booster station instead of an additional main at Folkestone. A Sulzer pump, discharging 1,500 g.p.m. was installed in another location involving a number of different reservoirs on the same distribution system. The pump was used to correct the flow into one of the reservoirs. *Bellmouthed Weirs and Tunnel Outlets for the Disposal of Flood Waters*, by W. J. E. Binnie. A model of a bellmouth overflow for the Ladybower reservoir was first made and tested. It was designed for a capacity of 4,200 c.f.s. and was 80 ft. from tip to tip. The normal circular overflow as at present designed is a smooth trumpet shape, tapered down to the discharge tunnel below. The amount of entrained air is equal to the volume of water discharged. The air was introduced to reduce the maximum vacuum but it meant a reduction of the capacity of the tunnel and, as at Lochaber, it exploded at the outlet or at the upper valve shaft with great violence and resulting damage. At Boulder Dam a step and a constriction had been introduced at the end of the channel to induce a rotary motion to the water and to check surging. Another expedient suggested to overcome the difficulty was the introduction of guide vanes. *Use of Models.* Model scales with ratios of 1:19 and 1:43 were used and results extrapolated to 20 times the size of the large model. This procedure is considered unsafe unless there is absolute confidence in the models.—*H. E. Babbitt.*

Water Supplies and River Pollution. A Summary of the Annual Report of the Water Pollution Research Board. Anon. The Surveyor, 91: 371 (1937). Unless satisfactory methods for the treatment and disposal of sewage and industrial effluents are more widely adopted there will be considerable difficulty

in providing the large volume of water of good quality necessary for domestic, agricultural and industrial purposes. The report includes an account of experiments which have been continued on the preparation and properties of materials used for softening hard water by the base-exchange process. It has been discovered that synthetic resins prepared from certain phenolic substances and tannins possess marked base-exchange properties and can soften comparatively large quantities of hard water. A method for the determination of lead in drinking water, involving the passage of the water through a filter containing magnesia and chalk, has been devised. Improved methods have been devised for the treatment and disposal of waste waters from dairies and factories.—*H. E. Babbitt.*

Exeter Waterworks Extensions. New Reservoirs, Filtration Plant, and Mains. ANON. The Surveyor, **91**: 381 (1937). A population of 72,000, occupying an area of 33,484 acres, consumes 3,340,000 gallons per day. The existing works comprise a river intake; a 30-inch dia. pipe to two reservoirs with a combined capacity of 4,500,000 gal.; six slow sand filters (with a total area of 7,840 square yards) which handle ⅔ of the water supply; a chlorinator; and a pumping plant. The new works involve alterations to the intake, the construction of a new 30-in. penstock, the resurfacing of the concrete floors of the reservoirs, and the extension of the existing mechanical filter plant at Pynes by the construction of 24 8-ft. dia. Bell mechanical filters, giving a capacity of 4,000,000 g.d. Three low-lift Worthington-Simpson centrifugal pumps with a total capacity of 7.5 m.g.d. will be installed at the filter plant. The new filtered water reservoir will have a capacity of 750,000 gallons. The Barley-lane storage reservoir on the distribution system has a capacity of 250,000 gallons. The new mains comprise 14-inch, 9-inch, and 6-inch diameter pipes.—*H. E. Babbitt.*

Chingford Reservoir: New Storage for Metropolitan Water Board. ANON. Civ. Eng. (British), **32**: 64 (1937). The reservoir with a capacity 3,000 million gallons, is located in the valley of the River Lea and forms one of the major sources of the East London area. The completion will take at least two years. The supply for the reservoir will be raised by pumping from a station sited in the north east corner of the reservoir area from the River Lea diversion. An aqueduct with a capacity of 20 m.g.d. takes the water from the navigation to the diversion. The method of reconstructing the Flander's Weir, which is an earth dam founded on blue clay, is described.—*H. E. Babbitt.*

Huntingdon Rural Water Supply. ANON. Civ. Eng. (British), **32**: 174 (1937). The water supply for an area of 233,985 acres with a population of 56,206 is obtained from shallow gravel wells located in the valley gravels of the River Ouse. One method of getting water from such gravels is the "Abyssinian tube" system, in which a number of small diameter tubes are driven into the gravel and their tops connected and water pumped from them. The demand for water is estimated as 175,000 g.p.d. Various other wells are pumped by electrically driven, turbine pumps. The water will be delivered into an elevated, concrete tank with a capacity of 100,000 gallons at a height of 98

feet. The water will be chlorinated. The total cost of the scheme is approximately £30,000—*H. E. Babbitt.*

The Problems of Water and Drainage. F. C. TEMPLE. The Contract J. 116: 1034, (1937). This presidential address of Inst. of San. Engrs. reviews water supply and sewage disposal in India during past 30 yrs. In 1905 very few Indian towns possessed piped water supplies and water usually came from river or inadequate reservoirs. No water was considered safe to drink without boiling. Methods of purification were just good enough to produce clear water and to avoid very frequent or complete failure. Effort was made 25 yrs. ago to improve conditions by using Puech Chabal filters without previous coag. and settling but these did not operate successfully. In a recent modern plant at Jamshedpur water may be aërated, treated with alum and sulfuric acid, settled, prepared in reaction tanks for filtration in rapid filters, acid neutralization, chlorination and dechlorination. Number of bored wells were put down but yield has fallen off. Some well waters contain high magnesium and others contain iron. Outstanding characteristic of Indian systems is high waste. One remedy being adopted is use of cisterns in each home to which water can enter only at rate sufficiently high to fill cistern in 12 hrs. Fact water only flows readily from tap when full leads consumer to use at rate low enough to keep cistern full. Description is given of sewerage and drainage systems in use and some ideas given as to future developments in water supply and sewage treatment.—*Martin E. Flentje.*

The Bedford Rural Water Scheme. F. R. MELVILLE. Civ. Eng. (British), 32: 124 (1937). The district has an area of approximately 13,000 acres and a population of 26,000. The plan provides for drawing bulk supplies from already existing water authorities. The work involved the laying of 154 miles of pipes between 3-inches and 9-inches diameter; the construction of an elevated steel tank with a capacity of 162,000 gallons, supported on a concrete tower 36 feet high; an electrically operated pumping station with centrifugal pumps with a capacity of 50,000 gallons per hour.—*H. E. Babbitt.*

The Huntington Pumping Station of the South Staffordshire Waterworks Company. ANON. Engineering, 143: 651–711 (1937). Troubles with and the dismantling of the old plant are described. The new pumping plant is in duplicate, each unit consisting of one transformer and one rectifier working in conjunction with one booster pump. There are four well pumps with a total capacity of 3,317 g.p.m. and four booster pumps of the same capacity. The power is supplied on three phases, 50 cycles and 6,000 volts through two transformers each with a capacity of 229 kva. The vertical spindle, shunt-wound, well-pump motors are standard, drip-proof, continuously-rated machines fitted with ball and roller bearings, each with a rating of 75 h.p. The well pumps are four-stage, bore-hole type, each stage being separate and of cast iron with integral guide vanes. The booster pumps are of two-stage type with single inlet impellers. In the new section of the 15-inch delivery main are a Venturi meter, a check value and a gate valve, each valve being fitted with a by-pass. The treated water tank has a capacity of about 20,000 gallons and

is constructed of brick masonry lined with asphalt. The major portion of the tank is covered with rolled steel chequer plates supported on steel joists. The Van der Made system of ozonisation is used on the water as it comes from the well. In this process the ozone is produced by subjecting the atmospheric air to a high tension, high frequency electrical discharge. The water containing solids and dissolved oxygen matter must first be treated by coagulation and filtration. The ozonising apparatus consists of 8 units each having 6 horizontal electrodes arranged in triangular form. These consist of stainless steel tubes which are inserted in glass tubes and so supported in them that there is an annular passage between the two. The current is discharged silently across the annular gap through the walls of the glass tubes to the water which is electrically grounded. The discharge passes, in consequence, through the air which is being aspirated along the annular passages and converts the oxygen into ozone. The duplicate air compressors into which the cooled and dried air is drawn are driven by a d.c. shunt-wound motor of 10 h.p. The plant has a peak load capacity of 84,000 gallons per hour. The Huntington Station is one of seven in the Hednesford system and, due to pumping conditions, it has only been possible to pump continuously at the rate of 38,000 gallons per hour. —*H. E. Babbitt.*

American Fountain Practice. E. E. R. Tratman. The Engineer (British), **163**: 242, 298, 328 (1937). Both height and the area of the water effects are factors in the design of fountains. Single, tall, solid vertical jets are often supplemented by a group of smaller jets surrounding the main nozzle, or by a pipe ring of small diameter having nozzles spouting either upward or outward. For a larger area a pipe ring of large diameter may have nozzles discharging upward and inward in a dome of water-hedge effect. For a curtain of water or a cascade effect, jets may spout from nozzles along a straight pipe of desired length. The water may also be sprayed instead of being discharged in solid streams. These spray jets may be flat or conical, the latter formed by nozzles having internal spirals which give a divergence of 30 to 60 degrees to the issuing stream. Centrifugal pumps driven by electric motors are used largely in fountain service but water is taken sometimes from the city mains and discharged to waste. Experimental work with subsequent adjustment is required for nearly every fountain installation. Economy in water consumption has been increased in some cases by the spraying of water through atomising nozzles. Illumination and architectural design of fountains in general are described and detailed descriptions of various fountains are presented including the Buckingham Memorial Fountain in Chicago, the fountains of the Texas Centennial Exposition, the Chicago "Century of Progress" fountains, and some standardised proprietary designs for small and moderate size installations.—*H. E. Babbitt.*

New Water Scheme for Durban, South Africa. Anon. The Engineer (British), **163**: 362 (1937). It is proposed to dam the Umgeni River, creating a reservoir with a capacity of 5,000 million gallons, with a gravity section, masonry dam, at a total cost of £1,700,000. The spillway will be 1,380 ft. long and 115 ft. above the river. There will be an aqueduct, 31 miles long, com-

prising a pipe line and four tunnels, with a capacity of 20 m.g.d. The diameter of the pipes will vary between 27 and 48 inches. Thirteen miles of road will be constructed through mountainous country at a cost of £50,000.—*H. E. Babbitt.*

A Few "Kinks and Gadgets" in the Operation of a Water System. CARL A. HECHMER. W. W. and Sew., **84**: 86 (1937). Tool board, dust exhaust fan, gas cylinder truck and cradle, pilot lights for chemical feeders, effluent sight bottle cases, are described.—*H. E. Hudson, Jr.*

Practical Electricity in the Plant. IV. Motors. MARSDEN C. SMITH. W. W. and Sew., **84**: 138 (1937). Presentation of the characteristics of synchronous, squirrel cage, induction, and variable speed induction motors. Pump rating for 40°C. temperature rise is recommended.—*H. E. Hudson, Jr.*

Haweswater Water Works. ANON. The Engineer (British), **163**: 534 (1937). The scheme includes the construction of a masonry dam 1,550 ft. long, 120 ft. high, and a maximum width of 112 ft.; a reservoir with a surface area of 974 acres and a capacity of 19,000 million gallons; an aqueduct 73 miles long comprising 30.5 miles of tunnel, 8.5 miles of covered channel, and 34 miles of pipes, all with a flow capacity of 30 m.g.d. The lakeside road, along the southeast border of the reservoir, is 4.75 miles long, is 20 ft. wide and contains two reinforced concrete bridges.—*H. E. Babbitt.*

Waterworks Intakes of the Great Lakes. BERT HUDGINS. Geographical Review, **22**: 457 (1937). Combined drainage area of Great Lakes is 298,000 sq. mi., 95,000 of which is water surface. Avg. annual rainfall is 30 in., its variation causing fluctuations in the lake levels, but rarely more than 2 ft. A rather constant outflow of 210,000 cu. ft. per sec. is maintained through the St. Lawrence river. Currents produced by winds in Great Lakes take the form of rather persistent counterclockwise eddies in each basin, fairly pronounced and regular on south and west sides of lakes, ill defined on north and east sides. Two types of waterworks intakes used, exposed crib type and the submerged intake. Exposed crib usually built above water and arranged to allow water to enter in through control doors. This type suitable for shallow water. Submerged type intake consists of domed-shaped capping of water main extended into lake. General flow of water in lakes towards outlet is negligible compared to currents produced by winds. Current caused by flow through lakes would ave. about 35 ft. per day, surface currents caused by winds will have an ave. of about 5% of velocity of wind. Currents and wind have effect on location of polluted water of 26 large cities taking water from the lakes. Ave. distance of intake from shore is ½ mi. and greatest distance about 5 mi. Ice sometimes of considerable trouble to intakes, kinds encountered include sheet, frazil and anchor ice. Other interesting information about lakes is given.—*Martin E. Flentje.*

Some Notes on German Waterworks Practice. JOHN BOWMAN. The Contract J., **116**: 875 (1937). Four rivers, Rhine, Weser, Elbe and Oder drain Germany from south to north and with their tributaries form a network of

waterways over most of surface of country. Most of the large cities are on river banks and until comparatively recent times most depended upon river for water supply. Recently many cities have gone to wells. Rainfall varies with distance from sea and height above sea level. In lowest lands from 20 to 22 in. ave. annual rainfall. In Hartz Mts. ave. is from 24 to 40 in. and in highest Bavarian Alps greatest rainfall occurs and averages 47 in. Rainfall often heavy, 3.9 in. in 24 hrs. is not uncommon, while showers of 1–2 hrs. duration with rainfall rates from 2.76 to 3.15 in. per hr. are frequent. Importance of pure wholesome water supply is well recognised and all cities and towns have excellent supplies. Several regional schemes have been inaugurated. 94% of water supplies are municipally owned, 4% belong to private companies and 2% are partly supplied by a company and partly by a city. This is true of Berlin. From nature of land and other conditions the use of upland storage reservoirs is not common, greatest proportion of water supplies comes from underground. Of 734 German towns and areas with 33,395,000 inhabitants, in 1931 in round numbers gallons supplied daily were as follows: from surface water 110 m.g.d.–11.397%, spring water 130 m.g.d.–13.50%, ground water 716 m.g.d.–74.143%. As an example of impounded upland supply probably best and most modern example is the Sose Res. in the Hartz Mts. This res. is the largest in Germany, capacity 5½ billion gallons, with a smaller upper res. total cap. is 5.65 b.g. Fed by Sose River, one of 3 rivers draining southwest area of Hartz Mts. Rainfall varies from 27.6 in. at lowest point in area to 67 in. at the highest. Ave. yearly run-off is 7.76 b.g., lowest (1911) 5.5 b.g., greatest (1914) 11 b.g. Res. has a drainage area of approx. 18 sq. mi. Max. height of dam is 180 ft. It is 26 ft. wide at the top and 828 ft. at the base. Was completed in 1931. Reservoir water is very soft and has a pH of 6.8 before treatment; after treatment 8.0. Water is treated with chalk water and alumina soln. before filtration in rapid gravity sand filters, cleaned with air and water. Purification works located just below dam. Ibid. 956 (1937). Hamburg, population over 1,000,000, was first German town to have a proper water system. First water supply was designed by William Lindley, an English engineer, who drew unfiltered water from a point 2 mi. above the city and distributed it to towers and city through 38 mi. of mains. Outbreak of cholera in 1892 resulted in thousands of deaths and led to introduction of filters. Extensive Elbe river filter plant developed but fluctuation of temp. and taste troubles from industrial wastes finally led to development of underground supply, which is preferred by German public health authorities. Hamburg supply now from 2 areas. In Billbrook area water comes from deep wells, 10 of which are nearly 900 ft. deep and have artesian water rising to 20 ft. above the surface, 6 wells are from 120 to 250 ft. deep, and about 20 wells are about 70 ft. deep. Total yield 9 m.g.d. of which 60% comes from the first 10 wells. Another area about 70 mi. in extent, contains 304 wells (bores); 259 from 45 to 75 ft. deep, and 45 from 75 to 300 ft.; yield about 40 m.g.d. Treatment consists of aeration, settling in channels and rapid double filtration at rates of 11 and 17 ft. per hr. Similar change to ground water is taking place at Altona, and adjoining town to Hamburg. Bremen draws its water supply partly from the river Weser and partly from the Sose Res. About 8 parts river water and 5 res. water are used. The supplies of Hanover, Frankfurt on

Main, Wiesbaden, Heilbron and Stuttgart are also briefly described. Ibid. 1033, (1937). Author believes the town of Munich has probably the most perfect water supply in the world. Water is ground water, unlimited in supply, free of impurities, crystal clear, tasteless, odorless, and collected at such an elevation that town is fed by gravity. Wells lie in 6 sq. mi. area in Mangfall river valley, and have been used since 1883. *Regional Water Schemes.* Good example of regional supply is Sose Res. of State of Hanover. 125 mi. long pipe line from res. to Bremen is Europe's longest pipe lines and delivers total of about 8 m.g.d. supplying 15 towns including Bremen with consumption of 3½ m.g.d. Steel pipe used throughout. Water from the Wurtenberg regional water scheme is distributed to 12 towns and 12 other special districts including 138 small towns and villages. Total population supplied 650,000. Max. consumption is 20 m.g.d., main pipe line 62 mi. long. In small towns water tanks are utilized to maintain pressure similar to air tank on hydraulic rams. German water systems contain approx. 90% of cast iron pipe, 10% steel. Water supplied almost entirely through meters. Total rainfall for years 1927-35 inc. is given and varies from a low of 540 mm. to high of 760 mm. per year. Unaccounted water varies from 15 to 25%.—*Martin E. Flentje.*

HYDROLOGY AND HYDRAULICS

Problems of Water-Boundary Definition. Median Lines and International Boundaries Through Territorial Waters. S. WHITTEMORE BOGGS. Geographical Review, July (1937) **22**: 445 (1937). Political boundaries that pass through bodies of water within the territory of two or more nations or states present several interesting problems. Water boundaries are marked by their peculiar problems of definition and demarkation. Author proposes a method of marking using a new idea of median line which is defined as line every point of which is equidistant from the nearest point or points on opposite shores of the lake, river or strait. This boundary line is recommended for definiteness of location. A method of setting up boundary limits of bordering lands on high seas is also given.—*Martin E. Flentje.*

River Flow Records and Waterworks Design. T. F. HENDERSON. The Surveyor, **91**: 524 (1937). Rivers and streams in this country form our principal source of water supply, and very little is known of the actual volume of water flowing down most of our rivers. We have at our disposal a long range of rainfall records, some dating back to 1677 and today the British rainfall organization has grown to nearly 6,000 observers. Haphazard, fragmentary and often vague information on the flow of rivers and streams often forms the basis on which the engineer designs his works. We ought to have all the information regarding the flow of rivers in similar form to the rainfall records. In America the flow of almost every river is measured by the Geological Survey. The information is precise and is valuable to engineers.—*H. E. Babbitt.*

Practical Hydraulics.. III. Measurement of a Head on a Weir. P. S. WILSON. W. Wks. and Sew., **84**: 105 (1937). Brief description of several simple gages.—*H. E. Hudson, Jr.*

Practical Hydraulics. IV. Float Gages. P. S. WILSON. W. Wks. and Sew., 84: 119 (1937). Floats, stilling boxes, gages with rigid stems or flexible wires, indicators and recorders are briefly discussed.—*H. E. Hudson, Jr.*

FLOODS

Flood Control. FRANK J. SALBERG. (East Bengal, India.) Eng. News-Rec., 118: 896 (1937). S. believes that American engineers have lost sight of fact that a river with its alluvial plain is natural phenomenon. Essential point is that all such rivers carry silt, which must be deposited. If deposition on flood plain is prevented by levees, silt must be carried to river mouth, where it will be deposited in building plains of future, thus lengthening river. River must therefore raise its bed, which will increase flood levels, necessitating raising of levees. Time must come when it is no longer feasible to raise levees or increase river's grade by straightening. Some scheme must be evolved to build up plains with river silt, first to replace natural growth of which they have been robbed during past 80 years of levee protection and after that to keep pace with river's natural growth. Only solution appears to be controlled spillways designed to flood and build up sectional areas, each with its discharge canal back into parent river. Under such scheme, large blocks of country would have to be taken over by state for period of their reconditioning.—*R. E. Thompson.*

Partial Flood-Control Storage Valuable in Extreme High Water. C. I. GRIMM. Eng. News-Rec., 118: 779 (1937). Diagrams are given comparing regulated and unregulated Williamette River flood stages between Eugene and Harrisburg, Oregon, one of 12 river zones that would be benefited by system of 4 reservoirs now under consideration. While proposed reservoirs will not hold larger floods within banks of rather limited channel, storage would be sufficient to eliminate 98 percent of monetary loss that would otherwise result. On basis of records from 1890 to 1936, adding one theoretical flood, it is estimated that average annual damage would be reduced from $567,480 to $11,300.—*R. E. Thompson.*

$800,000,000 Flood Control Plan. ANON. Eng. News-Rec., 118: 852 (1937). In report made public at hearing before House flood control committee on June 7, General Edward M. Markham proposed flood control program for Ohio and Mississippi Rivers and their tributaries which involves construction of numerous detention reservoirs, miles of levees, river walls and channel improvements and establishment of floodways on Mississippi.—*R. E. Thompson.*

Bellmouth Weirs and Tunnel Outlets for the Disposal of Flood Water. W. J. E. BINNIE. The Surveyor, 91: 786 (1937). Examples of five large reservoirs at which bellmouth overflows have been constructed are given. This type of overflow was chosen in place of the overflow weir and spillway channel generally adopted, in which there is no danger of the water immediately below the weir rising to such an extent as to interfere with the discharge. Owing to unsuitable configuration of the ground such works may be very costly and

the alternative method whereby the water passing over the weir of suitable length, provided by the bellmouth edge, falls down a shaft into a tunnel discharging into the stream below has been found to be economical. The reservoirs for which overflows are described include: Taf Fechan Reservoir, Silent Valley Reservoir, Pontian Ketchil Reservoir in Singapore, Burnhope Reservoir, and the Jubilee Reservoir in Hong Kong. Preliminary experiments were conducted on models, particularly to study the amount of air entrained by water falling down the shaft, and the influence which the direction of flow into the bellmouth has upon vortex formation. The experiments showed that the depth at which the vortex forms is not constant and that an asymetrical tangential velocity caused its occurrence at comparatively shallow depths on the lip. Siphonage over the lip of the bellmouth was also tested. With an inclined tunnel the model indicated that violent surging takes place and it is considered that the bellmouth overflow is only economically applicable to a vertical shaft discharging into a nearly horizontal tunnel. Pulsations occurring when a vacuum is formed are objectionable but they can be avoided by adopting a suitable shape for the bellmouth and restricting the velocity of discharge in the tunnel.—*H. E. Babbitt.*

Public Health Aspects of the Flood of March, 1936 in New York State. ANSELMO F. DAPPERT. J. N. E. W. W. A., 51:69 (1937). No public water supply, as a general rule, can be more dependable than the person entrusted with the responsibility for its care and operation. Supt. and operators should not only look after problems of routine operation but should search for those weaknesses that may produce failure or serious contamination of the supply in times of emergency. Floods create emergencies and this article brings former publications up to date and provides record of experiences upon which plans for the future action may be based. The 1936 flood in New York was caused by heavy rains and melting snow throughout drainage areas of the Susquehanna, Delaware, Mohawk and Hudson rivers. The value of the district engineering organization of the N. Y. health dept. was demonstrated. Health of people in flooded areas was safeguarded by, (1) preliminary warning of the possibility of floods, (2) issuance of general "boil water" warnings, (3) rapid contact by the district and central office engineers with affected communities, (4) general health aid by the state health dept. Brief summary is given of flood water supply problems at Binghamton, Endicott, Norwich, Granville and other communities. Generally, chlorine dosages were stepped up on all supplies and "boil water" warnings were kept in effect until safety of supplies was assured. In future emergencies district engineers of health dept. will get in touch with local health officers and water works officials, check conditions of supplies, anticipate possible difficulties, and leave instructions that the health dept. be kept advised. Main reliance must of necessity be placed upon local officials. Public water supply is to be given first consideration. Examples are given where lack of knowledge of plant piping and construction lead to unnecessary shortage of water in time of emergency. In any general plan for safeguarding public health during floods, author believes much of work must be directed toward training of local operators and officials.—*Martin E. Flentje.*

Public Health Aspects of the Flood of March, 1936 in Pennsylvania. W. L. STEVENSON. J. N. E. W. W. A., 51: 80 (1937). The widespread floods throughout Penna. in Mar. 1936 adversely affected public water works supplying 200 communities and about 2 million consumers. In 250 communities private water supplies were contaminated with flood waters and in 350 communities dwellings were inundated. About 100 water works were put out of service; in these, pumps were flooded in 60% of the cases, chlorine apparatus in 35%, clear wells in 23%, filters in 13%. There were however no epidemics of reportable disease in the flooded areas and only from 4 to 6 cases of typhoid fever could indirectly be connected with the flood. During floods 381 persons were on duty with the eng. bureau of the health dept. General "boil water" notices were issued in all areas subject to flooding. Drinking water was supplied to stricken towns in chlorinated motorized tanks. Conditions were aggravated by two distinct floods. After floods first attention was paid to rehabilitation of water works and boiling notices rescinded only after satisfactory results were received on bacterial samples collected from the system. Many private supplies were sterilized, pumped and analyzed and recommendations given for improvement. During emergency 950 tons of lime and quicklime and 115,000 lbs. of chlorinated lime were collected and distributed by state health dept. Flooding of several hard coal mines led to assumption by State of task of removing the impounded water for which $700,000 was appropriated. In 4 mo. 18 motor driven pumps removed 4300 m.g. of water from this source. Author believes absence of any resulting epidemic due to zeal and skill of water works employees, general boiling of all drinking water, sterilization of flooded private supplies, scouring out of organic deposits from streams by the first smaller flood and enormous dilution of second and major flood, and the preparedness of the State Health Dept.—*Martin E. Flentje.*

Public Health Aspects of the Flood of March, 1936 in Massachusetts. ARTHUR D. WESTON. J. N. E. W. W. A., 51: 90 (1937). The abnormally heavy rainfall that occurred over large areas of the water sheds tributary to Mass. streams during a period of high temps. when the ground was frozen and covered with snow of high water content resulted, during the week of Mar., 1936, in the greatest recorded run-off and strongest threat to purity of public water supplies experienced by Mass. Health Dept. Pptn. for mo. of Mar. on most of the drainage areas affected by floods was over 6 in. Normal and 1936 rainfall in inches respectively were, Jan., 3.81–7.28; Feb., 3.56–2.85; Mar., 3.98–8.13; 3 mo. total, 11.35–18.26. Run-off characteristics of Mass. streams varies as is shown in flood curves of Housatonic, Connecticut, Merrimack and Charles rivers. Compared to previous floods this flood was considerably larger as is illustrated by Nov. 1927 flood figures (1) and those for Mar. 1936 (2), given in cu. ft. per sec.; Charles River at "Charles River" gaging station, (1) 742, (2) 2500; Housatonic River at Great Barrington, (1) 5690, (2) 8500; Merrimack River at Pawtuckett Dam, Lowell, (1) 73,000, (2) 173,000; Conn. River at Holyoke Dam, (1) 180,000, (2) 222,000. The flow in cubic feet per sec. per sq. mi. of drainage area is also given and compared; for Charles River with a drainage area of 184 sq. mi. figure is 13.6, for Housatonic River with 280 sq. mi.—30.4, for Merrimack River with 4635 sq. mi.—37.3, and for the Conn.

with a drainage area of 8120 sq. mi. the figure is 27.4. 25 water supplies are listed as having been exposed to pollution and the difficulties encountered at Lowell, Lawrence, Methuen and Fitchburg are described in some detail. In none of these cities were coli-aerogenes group organisms found in the mains even though emergency supplies and treatments were used.—*Martin E. Flentje.*

The Ohio River Flood of 1936. F. H. WARING. J. N. E. W. W. A., 51: 103 (1937). Flood stages in which river becomes "bank-full" are not uncommon on Ohio River and occur on an avg. of once in every 2 yrs. Extreme flood heights occur throughout river valley usually much less frequently; as an example at Cincinnati low water level is 11 or 12 ft., ordinary flood stages of over 50 ft. occur every 2 yrs., stages of over 60 ft. causing considerable damage occur once in every 8 yrs., and extreme floods of over 65 ft. on an ave. not over once in every 25 yrs. Highest flood levels at Cincinnati have occurred in 1881—71 ft., in 1913—69.8, (in Jan. 1937—80 ft.). The probable frequency of such extreme floods is once in 182 yrs. for the 1881 mark and once in 126 yrs. for the 1913 mark. Following Mar. 17, 1936 the Ohio River was in extreme flood in its upper stretch of about 100 mi. from Pittsburgh to below the Wheeling district, while hardly more than ordinary flood height was obtained at Marietta, 170 mi. from Pittsburgh. This flood affected Ohio municipalities in a relatively minor degree. Of the 7 cities and 4 villages located along the 100 mi. flooded stretch, 3 systems supplying water to 5 communities were forced to interrupt supply, longest time out service being 4 days. Private supplies were polluted in half a dozen communities. No typhoid fever resulted in flooded area; a dozen cases developed in a small portion of one community on high land which purchased water from an adjacent one which experienced a temporary shut-down of the water supply due to the flood.—*Martin E. Flentje.*

FILTRATION

Filter Bed Troubles and their Elimination. JOHN R. BAYLIS. J. N. E. W. W. A., 51: 1 (1937). The belief that filter sand coated with a gelatinous film is more effective than clean sand is one reason keeping rapid sand filter media in good condition has not received attention deserved. Common plant trouble is experienced from filter bed clogging, pulling away from side walls and formation of cracks at surface. With good distribution of wash water and proper grading of materials most of filter bed trouble may be attributed to failure to remove all of the deposited material during washing of the filter. Washing by reversal of flow through bed cannot remove all of filtered material in sand without carrying over some of sand itself. Each washing results in retention of an increasing amount of material filtered from water which becomes more compact and through adherence to similar particles aids mud ball growth and formation. When grown sufficiently large and compact these larger mud ball masses may not stay at surface of bed and, if having a high enough specific gravity, may even sink down to gravel layer. Expts. made on clean sand and sand coated with gelatinous film show considerable

shrinkage in volume with increasing loss of head for coated sand with only slight shrinkage of sand kept clear with surface wash. May be explained by fact that clean sand particles rest directly on each other and cannot therefore be forced together whereas soft gelatinous film will allow considerable contraction under the 8–10 ft. pressure exerted mostly at surface of sand bed ready for washing. Amount settlement of sand in inches at 8 ft. loss of head for sand washed with usual method was slightly over 1 in., with sand kept clear with surface wash shrinkage at 8 ft. loss of head was less than 0.20 inches. Most filter beds exhibit pulling away of sand from sidewalls. Such cracks have been found to extend to depth of 18 in. in beds of 24 in. total depth. Sidewall cracks allow by-passing of portion of sand which is the finer portion and the most effective filtering medium, and also promote formation of clogged areas. Necessary factor in formation clogged areas is presence of an accumulation of mud or mud balls in filter. Mud balls tend to clump together at surface of filter during washing. When such a clump moving about strikes sidewall it frequently remains there and increases in size by adherence of other drifting mud balls. This clump is then held in place against wall when sand bed settles into position after washing, becoming compacted enough during subsequent filtering periods to finally remain in place during later filter washings. Sidewall location is most common for clogged areas. Small areas may exist without indication of presence on sand surface, larger portions readily shown by ridges and cracks. Filter washing rate influences position of mud balls in filter, higher rates with greater percentage of bed expansion resulting generally in more mud balls settling to the lower levels of the bed. *Volume of Mud Balls in Filters.* Because more mud balls remain near surface than in any other part of bed, measurement of mud balls in this portion will give indication of cleanliness of sand. Construction of a satisfactory sampling tube is shown of such size that 5 fillings of tube are equivalent to a 6 inch cube. Sand samples are collected from 4 or more places in bed and washed through a 10 mesh sieve by nearly submerging in water and gently raising and lowering ½ inch at time until sand and mud balls separated. Volume of mud balls then det'd. by displacement in cylinder graduate. B. gives a suggested classification of filter bed for cleanliness based on percent volume of mud balls found in upper 6 inches of bed. 0 to 0.1% mud ball volume is called excellent, 0.1 to 0.2% very good, 0.2 to 0.5% good, 0.5 to 1.0% fair, 1.0 to 2.5% fairly bad, 2.5 to 5.0% bad, and over 5.0% very bad. Additional wash should be provided when percentage of mud balls exceeds 0.2%. *Trouble at the Sand-Gravel Junction.* Much of the trouble in filters originates at the sand-gravel interface or junction where the sand expanded and put into motion during washing comes into contact with the gravel bed which is not expanded nor in motion. At such a junction jet action is bound to develop in any materials apt to be used in filters. Where washing rate is 15 g.p.m. per sq. ft., the avg. upward velocity of the water through the gravel should be less than 0.1 ft. per sec. Jet action results in displacement of fine gravel at point of jet and piling up between jets and may also cause piling up of mud balls in certain points of filter. *Grading of Material at the Sand-Gravel Junction.* Expts. by author indicate gradual transition from coarse to fine material is better than grading now used in many filter beds. Grading for sizes over 1.0 mm. in diam. show

follow approx. equation M equals K log D when M equals depth in inches material below the material 1.0 mm. in diam.; K constant, and D diam. of particles in mm. Value of 12 for K gives very good grading of material. The depth of material of 1.0 mm. diam. and finer has to be decided upon and also the size at and above which material will be screened and placed in the bed by hand. Kind of underdrains used influences size and thickness of coarsest material used in filter. Table is given showing application of formula to gravel layer in which first layer consists of material over 38 mm. in diam. (over 1½ in.). Proposed grading means paying more attention to coarse material in the sand than has heretofore been given. Most of sands will not contain enough of the sizes between 1.0 and 2.0 mm. and it will be necessary to supplement these with certain amount of coarse sand. *Cleaning Dirty Filters.* Discussion is given of filter sand cleaning with chlorine, caustic soda, raking, scraping surface, use of fire hose and ejecting sand from filter. General conclusion is that cleaning only after sand bed has accumulated numerous mud balls or has become badly clogged cannot be regarded as good practice. Only satisfactory procedure is application of cleansing force at each wash that will keep beds permanently in good condition. *Attempts to Maintain Filters Clean.* Various methods have been tried to keep filters clean. Increasing the settling time decreases the tendency to form mud balls considerably. Author believes settling period of 3–4 hrs. on lake water with surface wash to be more economical than enlarging settling basins. Revolving rakes not considered practical with present day filters and air and water wash has proven ineffective in certain plants. High rates of washing to maintain 50% expansion of sand bed materially improves conditions, especially over rates below 15 g.p.m. per sq. ft. (about 24 in. vertical rise per min.). Application of high rate of washing sometimes not possible because of loss of sand by being thrown over into wash water trough. *The Surface Wash.* Surface wash of filters not new, one of first patents for method issued in 1881. Also used in Champaign and Urbana, Ill. beginning in 1914–15 and Baltimore in 1924. Design of surface wash systems used at Chicago Exptl. Plant described. Latest has laterals located above wash water troughs with 1 inch down-pipes extending nearly to sand. 16 of these are spaced 34 in. apart each way for 100 sq. ft. filtering area. Brass caps drilled with 5/32 in. holes distributed wash water. With 10 ft. head on down-pipe, surface washing system gives 2.1 g.p.m. per sq. ft., with 20 ft. head flow is 3.1 g.p.m. Best results obtained with caps on end of down-pipes located about 4 in. above sand when filter is not being washed. When bed is expanded 2 to 3 in. by regular backwash, jets strike with their greatest force on the part of sand containing largest number of mud balls. Tests at 19 ft. pressure have shown surface wash keeps mud balls at conc. considered excellent—less than 0.1%. In tests bed was washed for approximately two minutes at 10 g p.m. rate and one min. at 14 g.p.m. rate of underneath wash and surface wash valve was open for about 3 min., opening this valve before underneath wash was started and stopping when higher rate started. *Suggestions for the Design of Surface Washing Systems.* If good backwashing system exists, max. amount of water that need be used in beds filtering water with max. tendency to clog is about 7 to 8 g.p.m. per sq. ft., where tendency to clog is slight 2 g.p.m. per sq. ft. is sufficient. In general pressure on jets should be at least

equivalent to 20 ft. of water and head of 50 or 60 ft. is better for filters which readily form mud balls. Where high pressure is available, full pressure may be used and if more than 50 ft. fewer jets or smaller openings used. With 5/16 in. holes in cap on down-pipe, 1 in. pipe should be used Down-pipes should be 24 and 30 in. each way when 4 to 8 g.p.m. are needed for each sq. ft. of filtering surface. Where it is known 2 to 3 g.p.m. are sufficient, spacing may be 30 to 36 in. apart. *Advantages of the Surface Wash.* No other system has been developed which will keep the filter bed as clean as with jets of water properly distributed and under considerable pressure when thrown into the top of a slightly expanded bed. The rapid sand filter is a vital step in usual process of water purification and it should not be allowed to become so fouled that it fails to do its job. It has also been shown that surface washed beds are more effective in filtering the coagulated matter from water during periods when coagulated matter penetrates deeply into the filter beds. *Effective Size of Filtering Material.* Author has suggested new method for detng. an effective size of filtering materials in which the eff. size is taken as the ave. of the 1, 2, 4, 8, 16, and 32% sizes. In stating a certain percent size, it means that this percent of the material by weight is of the size and smaller in diam. The uniformity coeff. is taken as the percent of the material by weight of a size 1.5 times the diam. of the 1% size. Clogging rate has certain definite relation to the size when detd. by author's method not true of method in common use and length of filter runs vary approx. as the 2.15 power of the diam. of the effective size. Illustrations are given of sand samples, various jet and velocity diagrams, and plans of surface wash systems.—*Martin E. Flentje.*

Operating Experience with Anthracite Filters. H. S. R. McCurdy. J. New Eng. W. W. Assoc., 51: 37 (Mar. 1937). A comparison is given of several anthrafilt (hard coal) filters with sand filters at the Crum Creek and Pickering Creek plants of the Phila. Suburban Water Co. Water treated has been uniformly of extremely good quality; water applied to the filters having an ave. turbidity of 2 and an ave. color 4 and 7. Water has been prechlorinated and filtered at rates from 50 to 70% of standard rates. At Crum Creek plant filter sand has an eff. size of 0.4 m.m. and uniff. coeff. of 1.47, anthrafilt eff. size of 0.6 m.m. in one filter and 0.7 m.m. in another, both grades having a uniff. coeff. of 1.60 or less, all beds being 30 in. deep. There has been little difference in efficiency of filtration as far as physical, chemical and bacterial characteristics is concerned. In 8 mo.'s observations filter runs for anthrafilt has been 78 hrs. ave. with a 0.96% wash water consumption, for sand filters ave. filter hrs. between filter washes has been 56 hrs. and wash water percentage has been 1.32%. Anthrafilt filters have been washed when the loss of head has reached 6–7 ft. and at a rate of 15 g.p.m.; sand beds have been washed at 17 g.p.m. at 8 ft. loss of head. At Pickering Creek 0.70 m.m. anthrafilt was compared with 0.38 m.m. sand for 5 mo. with very similar results. Ave. filter runs with anthrafilt were 87 hrs., for sand 44 hrs., with wash water of 0.67% against 1.16% respectively. It is expected continued observation will give opportunity for comparison under more widely divergent water conditions.—*Martin E. Flentje.*

Automatic Purification Plant for a Country Town Water Supply. W. O. O'NIAL. The Commonwealth Eng., 24: 407 (1937). Article describes a fully automatic water purification plant system with cap. of 20,000 g. per hr. for town of Numurkah, District of Victoria, Australia, pop. 1300. Water taken from a stream and irrigation supply. Plant consists of 30 min. mechanical mixing in circular steel basin equipped with a special S shaped agitator, this tank being inside a similar larger concrete settling basin with upward flow and 2 hrs. retention. Gravity filter with 181.5 sq. ft. area is arranged in 6 sections. During washing one section is washed with water from 5 other sections. Every operation is wholly automatic including throwing plant into operation, starting chemicals for coagulation, pH correction and chlorination; and filter washing.—*Martin E. Flentje.*

Cleveland's Experimental Pilot Plant at Baldwin Filters. W. C. LAWRENCE AND MATHEW M. BRAIDECH. W. W. and Sew., 84: 142 (1937). Experimental set-up for early experiments on activated carbon and the ammonia-chlorine treatment is described. Plant was rebuilt for mixing and coagulation studies. Baffled mixing chamber and hydraulic jump were constructed. These, together with chemical feed equipment, settling facilities, and experimental filters are described and illustrated.—*H. E. Hudson, Jr.*

Experience with Porous Plates for Filter Underdrain at Denver, Colo. O. J. RIPPLE. W. W. and Sew., 84: 85 (1937). Nine months operation of old tub-type filter with Aloxite plates indicates plates are satisfactory if clogging is prevented by proper water treatment.—*H. E. Hudson, Jr.*

Filter Sand Permeability Studies. F. T. MAVIS AND E. F. WILSEY. Eng. News-Rec., 118: 299 (1937). Tests of Iowa River sand and Standard Ottawa sand showed that: (1) The coeff. of permeability varied inversely as the coeff. of viscosity of the water. (2) The coeff. of permeability for the angular Iowa River sand varied as the 6th power of the porosity, and that for the rounded Ottawa sand as the 5th power. (3) The coeff. varied as the square of the diameter of the sand grains. (4) The coeff. of the rounded Ottawa sand was 50% greater than that of the angular Iowa River sand for unigranular samples having the same grain-sizes and porosities. (5) The velocity of flow through unigranular samples of Iowa River sand may be computed by the following formula with a mean absolute error of 2%: $v = 980\,d^2\left(\frac{p}{40}\right)^5\left(\frac{t+10}{60}\right)\frac{h}{l}$, where v = apparent velocity of flow through the sand column, in ft. per day, d = diameter of sand grains, in mm., p = porosity of sample, in % of loose vol., t = temp. of water, in °F., and $\frac{h}{l}$ = hydraulic gradient. The velocity through blended samples of Iowa River sand may also be computed by this formula with a mean absolute error of 15%, if d is the diameter of the largest grains in the finest third of the sample by wt. (6) The velocity of flow through blended samples of Iowa River sand may be computed by Hazen's formula, $v = c$

$d_e^2\left(\frac{t+10}{60}\right)\frac{h}{l}$, (in which $c = 2{,}300$ ft. per day) with a mean absolute error of 10%. The Iowa River sand was tested as (1) pit-run sand, (2) as uniform granular sand (separated by sieves in geometrical series of $\sqrt{2}$) from 0.39 to 1.98 mm. average diameter, and (3) as artificial mixtures in which the uniformity coefficient was under laboratory control. The Standard Ottawa sand grains ranged in size from 0.68 to 0.93 mm., an average diameter of 0.80 mm. The results of the tests are shown graphically.—*R. E. Thompson.*

IRON REMOVAL

Iron Removal and pH Correction Plant. J. W. Greenleaf, Jr. and B. F. Snow. W. W. Eng., 90: 330 (1937). A 10 g.p.m. experimental plant was built at Norwood, Mass., to study iron removal and corrosion correction problems. Final plant consisted of two aërator basins 18 x 40 feet in plan, using "Spraco" full cone spray nozzles, followed by coke contact beds. Water enters the bottom of the first bed, which is 15 x 30 feet in plan through a slotted manifold of half tile and flows upward through four feet of coke and out over a weir with a twenty foot crest into a collecting channel, which feeds the tile manifold in the second bed. The beds can be cleaned by reversing the flow or by the use of a hose stream. Dry feed machines are provided to feed lime or soda ash as the water passes from the contact beds to the mixing chamber. After coagulation the water is passed through sand filters. The plant is entirely automatic with the exception of the high lift pumps.—*Lewis V. Carpenter.*

Iron in Textile Water Supplies. Anon. Wool Rec., 50: 925 (1936). Iron in water supplies may be derived from natural or adventitious sources, e.g. the gathering ground or piping system, and be present both in suspension and in solution. For most textile work the water should not contain over 0.25 p.p.m. iron. Iron in suspension may be removed by filtration with or without preliminary coagulation. In softening water by lime-soda, the calcium carbonate precipitated frequently carries down the iron in suspension. With zeolite softening or water which does not require softening, a special iron removal process, e.g. treatment with sodium aluminate or aluminum sulphate, is necessary. Iron in solution may be removed by aëration followed by coagulation and filtration. Water containing iron and organic matter is difficult to treat as iron humate is not removed by aëration. The easiest method of treatment is to add a powerful oxidizing agent, e.g. sodium hypochlorite, or bleaching powder followed by an alkali to precipitate the lime as carbonate which then carries down the iron precipitated by the oxidation. There is, however, a prejudice against the use of chlorine or other strong oxidizing agents for water for textile purposes. The water may be treated with alum followed by soda ash or lime or both. In extreme instances, colloidal earths such as kaolin or bentonite may be used. Zeolite water softening may remove small amounts of iron in solution but suspended iron clogs the plant and reduces the softening efficiency. Dissolved iron is removed by the zeolite but treatment with salt solution does not regenerate iron zeolite. The effect of iron on certain wool dyestuffs in acid dyeing may be controlled by dyeing

in sulphuric acid instead of in a weak organic acid or by adding oxalic acid to the dyebath (0.025-0.25 lb. of oxalic acid per 100 gallons of liquor). The corrosion of iron pipes and of other metals, such as lead, aluminum and zinc, may be prevented by treating the water with sodium silicate which forms a protective film on the metal. The sodium silicate usually employed has a silica : sodium ratio of about 3:25. A suitable dosage is 4 oz. per 1,000 gallons. This amount of silicate does not usually cause precipitation and has very little effect on washing, scouring, bleaching or laundering. It should not be used for acid dyeing in circulating machinery. The treated water has a pH value of 8.5-9.0. Dissolved iron may be detected by the violet or brown coloration produced with thioglycollic acid in the presence of ammonia. Suspended iron must be removed by filtration, ashed and dissolved in acid before testing. Thioglycollic acid detects both ferrous and ferric iron because it reduces the ferric iron to the ferrous state.—*W. P. R.*

The Mechanism of the Phenomenon of the Exchange of Bases. G. AUSTERWEIL. Bull. soc. chim., 5: 1782 (1936). Glauconite was triturated with solutions of calcium chloride (the solution was renewed until it was saturated), washed until there was no chloride in wash water, then dried to constant weight at 102-105°. An aliquot part of the glauconite was placed in contact with aqueous magnesium chloride solution of equivalent concentration. After mixing, solid was found to have taken up 80 percent of magnesium. The glauconite was then removed from liquid and washed thoroughly. The wash water was added to the solution and mixture concentrated to original concentration of the magnesium chloride solution. This was placed in contact with new aliquot of glauconite treated with calcium chloride and procedure repeated. It was found that 80 per cent of magnesium ions remaining in solution were taken up again, indicating that base exchange takes place according to law of extraction. These figures were checked by treating the glauconite with sodium chloride and determining calcium and magnesium going into solution. Magnesium was found to be distributed between glauconite and solution according to distribution law in proportion to their respective solubilities (4:1). This confirms conclusion from previous work (C. A. 26, 4004, 5508) that base exchange is regulated by laws of extraction, the solid taking the part of a nonmiscible liquid. A correlation was found between the extraction formula and the empirical adsorption equation, shown to govern base exchange between constituents of soil and aqueous solutions of cations.—*R. E. Thompson.*

CHLORINATION

Water Chlorination Experience. F. O. A. ALMQUIST. J. New Eng. W. W. Assoc., 51: 41 (1937). Successful chlorination requires faithfulness, common sense and in some cases a little ingenuity on part of the operator. Problem may be divided into plant installation and plant operation. In planning installation amount and variation of water consumption should be known with max. and min. flows and daily variations with possible fire demands. Chlorine demand of water should be known for detn. of chlorinator capacity. Point

of application should in all cases be before first service and sufficiently far ahead to allow at least 10 min. contact time, with 30 min. where chlorine and ammonia is used. Main pressure must be known and for solution type machines water pressure must often be raised for injection of the chlorine solution into the main. In Conn., duplicate hydraulically operated pumps are preferred to electrically driven pumps in spite of wasted water. In some cases electrically driven pumps have been provided together with an hydraulic pump which automatically starts up on any interruption of electric current. Duplicate chlorinators are also recommended. Building should be of sufficient size, fireproof if possible, above ground and having ventilators near the floor. For hypochlorite installations room 8 ft. by 8 ft. in plan with adequate head room is sufficiently large, with liquid chlorine machines size of room must be adapted to type of equipment to be installed. Arrangements must be made to keep temp. at 50–55 F. for dry feed equipment and at 70–80 F. for solution feed machines with fuel storage of at least 24 hrs. Testing tap for residual chlorine detn. should be 200 ft. below point of application to insure adequate mixing. Conn. has 94 chlorinator installations serving 103 communities and total population of 1,139,000 (approx. 79% of state's inhabitants). In operating plant changes in chlorine demand must be met with corresponding changes in the chlorine dose. Author points out in new installations disagreeable tastes and odors may result when chlorine is first applied, caused by combination of chlorine with organic matter on pipe interior. This may sometimes be avoided by starting off with a low dose and gradually increasing to desired point within a period of 4 or 5 weeks. Chlorine applied must be regulated by residual chlorine tests, in Conn. recommended residual for surface supplies is usually 0.20 p.p.m. after a 10 min. contact period. In some cases lower than 0.20 allowed but never below 0.10 p.p.m. Frequent tests should be made. Limitations of ortho-tolidine test are briefly discussed. A bluish-green color on application may indicate more reagent is required to give necessary pH for proper color formation. On cold waters, water should be warmed to 60–70°F. to obtain best results and residual detnd. in 10 min. A chlorinator should be visited at least once each day to observe functioning of apparatus, make required tests, to weigh cylinders and to record operation procedures. Some tastes and odors ascribed to chlorine in water would be present without chlorination. Investigations have failed to show chlorine responsible for death of fish, usual causes having been quick change in water temp. and over feeding so as to foul water. Other water works uses of chlorine are briefly discussed.—*Martin E. Flentje.*

An Investigation of the Katadyn Treatment of Water with Particular Reference to Swimming Pools. ROBERT SHAPIRO AND FRANK E. HALE. J. N. E. W. W. A., 51: 113 (1937). Extensive expts. on the use of colloidal silver in minute quantities to sterilize water were made by the authors in the Mt. Prospect lab. and in a public swimming pool. Process known as Katadyn Process. Dosage of treatment is usually expressed in "gamma per liter," a gamma being 0.001 milligram. Literature indicated effective doses to be from 50 to 200 gamma or 0.05 to 0.20 p.p.m. In the swimming pool tests it was attempted to maintain a dosage of 150 gamma in the pool water, a water that

was recirculated, treated with alum and soda, filtered, and the Katadyn Process introduced between the filter and the pool. In lab. 7 strains of *E. Coli* were used, 18 hr. transplants and 1 loopfull in one liter of tap water allowed to stand for 2 hrs. for homogeneity. During the time that 200 gamma was being produced by electrolysis in water considerable sterilizing effect on the *E. Coli* was accomplished and 100% removal was obtained in 10 min. 300 gamma silver produced 1 p.p.m. turbidity. Catskill water treated with 300 gamma and allowed to stand 24 hrs. exerted considerable sterilizing effect on *E. Coli* when reinoculated; some, but insufficient, sterilizing action was found on a similar sample allowed to stand for 6 days. In another test 7 dosages from 15 to 300 gamma were added to Catskill water from a swimming pool and a dosage of 30 gamma was found effective after 40 min. contact period. Lab. tests on salt water from the St. George Hotel pool were unsuccessful apparently due to ammonia content. A large number of daily bacterial results on the pool test are tabulated giving the bacterial results before and after treatment, as well as various physical and chemical results. Authors feel that in the present stage of development Katadyn Process cannot be approved in swimming pools because the 37 degree count of bacteria is not affected by process, and among these bacteria may be disease germs affecting the eye, ear, nose and throat; when treatment is effective the 2 hrs. contact time required is undesirable; treatment must be studied with the particular water in which it is to be used; ammonia present in water prevents obtaining good results; higher dosages cause decided turbidities; at present there is no adequate simple test for detn. of silver in pool water; question is raised as to economy; possibility of production of disease called "argyrosis" in which the skin is permanently darkened by a deposit of silver.—*Martin E. Flentje.*

Germicidal Properties of Chlorine Compounds. DAVID CHARLTON AND MAX LEVINE. Bull. 132, Iowa Eng. Experiment Station, (1937). Methods used in estimating the strength of chlorine disinfectants are the same as those employed in analyzing hypochlorite bleaching solutions. Original term "available chlorine" has been retained in spite of objections to its use. Exact nature of disinfecting action of chlorine is controversial. Present study made to detn. relative germicidal activity of various forms of chlorine, the effect of pH, organic matter and other factors. A brief historical review is given of the use of hypochlorites, chlorine and chlorine and ammonia. The disinfecting action exerted by hypochlorites and by chloramines is evidently not well understood as evidenced by references to numerous published articles. The observed differences in the ratio of disinfection of the two types of compounds are of interest and study of various factors involved might give information of germicidal process. Hypochlorites readily attack organic matter and some seeming inert materials adsorb hypochlorites, whereas certain types of organic matter react with hypochlorites to give chemically combined chlorine. The iodometric and ortho-tolidine methods of measuring the available chlorine do so differently in presence of suspended matter and include various amounts of adsorbed and combined chlorine which do not have germicidal power. The importance of giving careful consideration to the presence of any kind of added substance either in disinfection tests or in the practical application of chlorine

compounds cannot be overemphasized. Test organism employed in these studies involving germicidal action of common chlorine compounds and effect thereon of chlorine conc., pH and temp., were spores of *B. metiens*. Solutions were Chloramine-T and 2 commercial hypochlorites, Perchloron and HTH, all evaluated by detn. of the available chlorine content. Spores were chosen for study to minimize the danger of rapid death rates as with non-spore forming bacteria in low conc., and to prevent changes in pH of test solution. Some advantages of using spores are given as (1) higher conc. of disinfectant could be used, (2) studies were possible over wider range of temp. and pH, (3) uniform suspensions of test organism from standpoint of numbers and resistance could be made up from day to day, (4) exposure to distilled water for periods longer than test did not affect number of viable cells or resistance to reagents. Criteria of death used was failure of additional spores to develop on colonies on nutrient agar in 24 hrs. at 30°C. Initial conc. of 300,000 to 400,000 spores in 5 c.c. was employed and killing time was defined as that time required to destroy 99% of exposed organisms. Experiments with Chloramine-T. The effect of pH on the germicidal power of chloramine-T was detd. and in first tests with 200 p.p.m. available chlorine resulting death rate was found to be very low. Conc. range of 1000 to 4000 p.p.m. available chlorine then decided upon. To detn. pH range that could be studied, preliminary tests were made to find out what alterations in reaction could be made without injuring spores. A pH of 4.2 was slowly germicidal at room temp., 43% of spores being killed in 4 days and 76% in 9 days. pH's of 5.85 and 9.35 were not germicidal at room temp. for 12 days. The killing time for the removal of 99% of the spores was then detnd. with doses of chloramine-T of 1000, 2000, and 4000 p.p.m. available chlorine at 25°C., varying the pH between 5.85 and 9.35. The 1000 p.p.m. available chlorine dose was tried at pH values of 8.6, 7.0, 6.4 and 6.0. The killing time ranged from 97 to 15 hrs. with lower pH the most rapid. Effect of pH pronounced. At 2000 p.p.m. and 7.0 pH killing time ranged from 64 to 5.4 hrs., and at the 4000 p.p.m. dose the killing times were 23.5 to 2.6 hrs. At pH 6.2 killing times were 27, 12 and 5.4 hrs. for the 1000, 2000 and 4000 p.p.m. conc. of available chlorine respectively. In each case reduction of killing time is about 55% for doubling of conc. In temp. effect study, 2000 p.p.m. dose used at pH of 8.7 and 6.0. Results show a rise of 10°C. at pH 6 reduced killing time 82% and at pH of 8.7 a 71.5% reduction was found. Various other control tests were made to demonstrate use of spores good exptl. means. *Experiments with Hypochlorites.* In one set of expts. calcium hypochlorite soln. contg. 100 p.p.m. available chlorine exhibited almost same germicidal power as soln. 10 times this conc.; killing time being about 70 min. Indicates "available chlorine" not a measure of germicidal power. Possibly due to pH effect, 100 p.p.m. soln. had a pH of 10.4; one of 1000 p.p.m. conc. pH of 11.3. When using dose of 1000 p.p.m. but with pH adjusted to 7.3 destruction of spores so rapid accurate test could not be made. 99.9% destruction was accomplished in 20 sec. with 100 p.p.m. dose and pH 9.6 killing time of 21 min. obtained. In one test 0.08 grams per liter of ammonium chloride was added to soln. of 100 p.p.m. available chlorine calcium hypochlorite soln., the ammonium compound being just sufficient to meet theoretical ratio of chlorine

to ammonia of 4.2 to 1. This resulted in change of pH of hypochlorite soln. from 10.4 to 9.8. Killing time with this soln. was 27 min. showing germicidal power greater than expected. pH changes did not affect the germicidal power of chloramines to an extent anything like that shown by hypochlorites. Of the 3 types of chlorine compounds studied, (1) chloramine-T exhibited the weakest germicidal power, (2) monochloramine was more strongly germicidal than hypochlorite when the comparison was made in highly alkaline solns., at reactions below pH range of 9.5 to 10.0 hypochlorites were more germicidal than monochloramine or the resulting mixture of mono- and dichloramine. Oxidation potential of chloramine-T solutions were found unsatisfactory as measure of germicidal activity. Expts. support contention that in disinfection with hypochlorites undissociated hypochlorous acid is the most significant germicidal agent. In disinfection with chloramine compound, chloraminé-T, it appears hypochlorous acid does not play the significant rôle—the disinfecting action in these compds. appears to be due primarily to the positive chlorine ion present.—*Martin E. Flentje.*

The "Otto" Water Ozonising System. ANON. The Engineer (British), 163: 575 and 648 (1937). Atmospheric air is first drawn through a desiccator containing layers of calcium chloride and coke. This air then passes between glass plates which are used as dielectrics, and across the gaps between these plates high tension current is discharged in a silent violet flame. The current has a voltage of 20,000 and a frequency of 500 cycles. The ozonised air is drawn through an aperture in the dielectrics and passes through a stoneware pipe to the emulser, where it is mixed with the water under treatment. Current consumption of 171 kwh per million gallons is reported. The installation at Knott Hill reservoir, with a capacity of 60,000 gallons per hour, is described. —*H. E. Babbitt.*

The Cumasina Process for the Disinfection of large Quantities of Drinking Water, Swimming Pools, or Water for Industrial Uses with Silver. W. KRUSE AND M. FISCHER. Gesundheite Ingenieur, 59: 312 (1937). Fischer found in 1929 that metallic silver can easily be made strongly oligodinamic by exposing it to an electric current of low voltage. Very finely dispersed silver chloride is thereby formed as the active substance. This is the "Cuma" (cum argento) process. If the material used for the anode is not attacked by the chlorine, the chlorine formed acts as disinfectant, so "Sina" (sine argento) process. Both methods use the ionization of the chlorine and are therefore taken together as the Cumasina process. One amp. hr. dissolves about 4 gm. silver. The disinfection of drinking water requires 10 to 20 mg. silver for 1 cu. m. (0.01 to 0.02 p.p.m.), swimming pool water 0.05 p.p.m. One swimming pool in Leipzig containing 20,000 gallons requires a current of 1.25 amperes with 9 v. The silver anode weighs 1 Kg. and has to be replaced every 3 to 4 weeks.

As the advantages of the methods are claimed: no tastes or odors are produced, there is therefore no reason for undertreatment to keep out odors. Overtreatment has no detrimental effect as the silver in the small amounts used is harmless. The regulation of the dosing is done by controlling the

electric current. The apparatus needed is very small and requires little control labor. Even ordinary distilled water contains enough chlorides to be used for the process. Algae are also killed.

Disadvantages of the process are: Its cost is slightly higher than chlorination. It requires 3 to 6 hours storage of the water after introduction of the silver to obtain satisfactory bacterial results.—*Max Suter.*

The Cumasina Process for the Disinfection of Drinking Water. Its application in residences, institutions, on voyages, and in the field. KRUSE AND FISCHER. Gesundheits Ingenieur **60**: 10 (1937). Describes methods to produce active silver chloride for the disinfection of small quantities of water. For residences either an apparatus that is screwed to the valve or one that can be set in a tank can be used. In both a current is passed between two silver electrodes. As source for the current can be used either dry or storage batteries. One ampere produces in one second about 1 mg. silver. Water treated in the evening is sterile in the morning. Hard water requires more silver than relatively pure water. Organic admixtures reduce also the effect of the silver. Similar results are obtained by the use of a prepared active silver solution (Cumasina liquidum) containing 1000 p.p.m. of colloidal silver chloride. Eight drops to 4 ml. of this solution are required for one gallon. A powder of active silver has also been prepared. Both the solution and the powder can be used for the disinfection of wounds. A similar apparatus to that used in tanks mentioned above has been constructed with platinum electrodes. This apparatus produces chlorine for the disinfection of the water. One ampere furnishes 0.16 mg. active chlorine per second. The advantage of the chlorine apparatus is in its time saving feature.—*Max Suter.*

Comparison of the Germicidal Efficiency of Hypochlorites of High and Low Alkalinity. S. M. COSTIGAN. J. Bact., **34**: 1 (1937). Results show the plate colony counts and dilution methods for measuring bactericidal efficiency to be in agreement and indicate that, with the hypochlorite dilutions used in the tests, the organisms were definitely destroyed and therefore bacteriostasis was not a factor. The dilution method gives a higher estimated bacterial population than the plate count method, probably due to the fact that a liquid medium is better adapted to bacterial growth; also, on agar plates, clumps of organisms may be present giving a lower colony count than would be estimated in dilution tubes. A highly alkaline hypochlorite under the conditions of this test was found not to be as efficient germicidally as one of lower alkalinity.—*Ralph E. Noble.*

Ozonising Plant at Knott Hill Reservoir, Ashton-Under-Lyne. ANON. Engineering, **143**: 605 (1937). The plant at the Knott Hill Reservoir is the second of its kind installed in Great Britain. The reservoir, which holds 64 million gallons represents about eight weeks supply. The decay of algal growths give rise to objectionable conditions in the water which cause complaints. This condition has been overcome by the construction of a 350,000 gal. covered reinforced concrete reservoir. The "Otto" process of ozonization of the water has been selected. The dried air is delivered at the bottom of the

9-unit ozonizer. Each unit consists of one high tension and one low tension element. These are of metal and are water-cooled internally. They are machined on the faces with which a plate-glass sheet, covered with tin foil on the inner side, is kept in close contact by springs. The current is used at 20,000 volts and 500 cycles. The ozonized air leaving the producer is led by means of earthenware pipes to the apparatus in which it is mixed with the raw water. An excess of ozone is usually maintained in this emulser. A 10-day test has shown the quality of the water to be quite satisfactory being improved from a dull green shade to a clear sparkling appearance.—*H. E. Babbitt.*

GROUND WATER

Wells for the Water of Hawaii. NORAH D. STEARNS. Eng. News-Rec., **118:** 450 (1937). On Island of Oahu, Hawaii, where extensive use of drilled artesian wells has seriously lowered ground water elevations in some places to point where invasion by salt water is practical reality, new type of well is being used which minimizes this danger yet permits increased withdrawal. Known as the Maui well, this method of water development utilizes artesian basin but avoids salt water contamination by skimming fresh water off underlying layer of heavier sea water. It consists of inclined shaft from ground surface to water table level, where one or more infiltration tunnels are extended horizontally at zone of saturation. Pumps, located in chamber at base of shaft, elevate water to surface. Details are given of 6 installations in use or under construction, together with history of Honolulu water supply system, which includes 2 such wells. Wells operating on same principle have been successfully employed on Island of Maui for some 35 years.—*R. E. Thompson.*

Underground Water Supplies. ANON Civ. Eng. (British), **32:** 197 (1937). Several instances are referred to in which large industrial users of water have driven wells in the near vicinity of a public water supply, causing a shortage of water, without the water undertaker having any redress. A plea is made for remedial legislation because the steady drop in level which is taking place in a number of artesian or semi-artesian areas is given not only water undertakers but private individuals and companies cause of serious alarm.—*H. E. Babbitt.*

Irrigation from Pumped Wells. W. HOLBROOK. Civ. Eng., **7:** 473 (1937). The large scale practice of well irrigation in this country began about thirty years ago, and was due largely to four factors: (1) The increasing cost of developing supplies from streams, (2) the need of supplementary supply for some gravity systems, (3) the improvements made at about that time in prime movers for isolated units, and (4) the introduction of the vertical turbine pump. Ground water in quantity may be present (1) in the refill of broad stream valleys, (2) in beds of sand and gravel in inland basins, or (3) in a deep water stratum under pressure, which often supplies artesian flow when conditions are right. Water-bearing formations are often a combination of firm sandstones or conglomerates, loose gravel, gravel and sand mixtures, and unmixed sand, often quite fine. It is imperative to case a deep well. Sand

that cannot be held back from the well must be pumped out; this process is termed "developing the well". It is often accomplished by using a larger pump than the one intended for permanent use, or by accelerating the pump to get a larger flow. If the use of ground water over a large area continuously exceeds the natural replacement, the water table will drop progressively. The matter of water temperature is often discussed. There is an obvious advantage in supplying plants with fairly warm water. We might expect ditch water to have an advantage over well water in the summer, but the advantage accrues to well water the rest of the year. It may be expected that in the future, irrigation by pumping will be developed more extensively in the humid than in the subhumid and arid districts.—*H. E. Babbitt.*

Well Supply from Fine Sands Increased During Drought. E. T. ARCHER. Am. City, 52: 82 (1937). The ground water supply for the city of Amarillo, Texas consists of an artificial lake surrounded by ten gravel-wall wells. The water is obtained from a stratum of fine sand which is pumped with the water by air-lift. It passes through sand-traps and flows by gravity to a small reservoir adjacent to the pumping plant. Back-blowing the wells and replacing the sand with gravel has increased the yield from 160 gpm. to about 700 gpm. in ten years.—*Arthur P. Miller.*

Cleaning Wells with Acid and Consequent Health Hazards. E. NAUMANN. Gas- u. Wasserfach 79: 623-4 (1936). Deposits in wells are frequently removed by treatment with dilute acid (usually hydrochloric) containing an inhibitor. Considerable quantities of hydrogen, arsine, carbon dioxide and hydrogen sulfide may be evolved during process; therefore, if operators must work in closed well chamber, hose masks should be worn and life-lines provided. Fatal accident due to these gases at Breslau is discussed.—*R. E. Thompson.*

Ground Water Levels in Utah. ANON. Eng. News-Rec., 118: 597 (1937). Water levels in most of larger ground water areas of Utah were higher in fall and winter of 1936 than in corresponding period of 1935. During 1936, some 3700 measurements were made in 850 observation and miscellaneous wells. Higher levels are due in part to increased precipitation and in part to adoption of conservation measures, consisting chiefly of control of waste from artesian wells. Most ground water basins in Utah are artesian.—*R. E. Thompson.*

Demand for Cooling Water at Wichita Exceeds Underground Supply. ANON. Eng. News-Rec., 118: 746 (1937). Arkansas Valley has fairly coarse water-bearing sand 20-25 feet deep over impervious shale, which will supply 800,000-1,000,000 gallons per day from wells with not less than 500-foot spacing in all directions, equivalent to 150,000 gallons per acre. This is sufficient for cooling residences but not for multi-story business buildings. During summer of 1936, ground water all but disappeared in a few locations. On basis of experience with large buildings, residences cooling 1,000 square feet of floor space would consume 10,000 gallons per day when operating full time, equivalent to 50,000 gallons per acre per day when building density is 5 homes per acre. Return of well water to ground to conserve supply is considered doubtful expediency

and of no value if universally adopted. In one case, a well apparently drew water from outflow from return well in another building, water temperature being 92°F. For residences, return to ground could be effected through lawn sprays or sub-irrigation drain tile.—*R. E. Thompson.*

Santa Clara Valley Subsidence Has Now Reached 5 Feet. E. E. STOHSNET. Eng. News-Rec., 118: 479 (1937). Repeated rerunning of first-order level lines at intervals of several years in Santa Clara Valley near city of San Jose, California, has shown continuous settlement of benchmarks. Area affected includes about 200 square miles and extent of settlement reaches maximum of slightly more than 5 feet in business district of San Jose. In vicinity of city, during past 15 years owners of deep wells, some of which are 800 feet deep, have been puzzled by apparent rising of well casings and pumps, necessitating removal of protruding portion of well casings at regular intervals in order to keep pumps on their bases. Some pumps have been lifted off foundations at rate of 2-3 inches per year, total rise in some instances being 2 feet. This suggests that only small part, if any, of subsidence can be ascribed to earth movement of deep-seated origin. Cause seems to reside in first few hundred feet below surface.—*R. E. Thompson.*

Land Subsidence Caused by Pumping. O. E. MEINZER. Eng. News-Rec., 118: 715 (1937). Writer believes that there is no reasonable doubt that subsidence in Santa Clara Valley (cf. previous abstract) is due to withdrawal of ground water. Magnitude of phenomenon of withdrawal of water from storage in artesian aquifers by compression, when buoyant force of artesian pressure is diminished, first became evident to M. during work in North Dakota. (See Water Supply Paper 520-E and also Economic Geology, 23 pp. 263-291, "Compressibility and Elasticity of Artesian Aquifers.") It would not be surprising if subsidence of some degree due to pumping were found to be much more general than is now supposed.—*R. E. Thompson.*

Causes of Land Subsidence. F. R. HARRIS. Eng. News-Rec., 118: 858 (1937). Further discussion of theory of subsidence due to withdrawal of ground water (or oil).—*R. E. Thompson.*

Long Island's Ground Water Problem. RUSSELL SUTER. Eng. News-Rec., 118: 697 (1937). Long Island ground water resources, which are entirely dependent on rainfall on the island, are being seriously impaired by uncontrolled pumping. Most of water under Brooklyn, much of that under Queens and some along south shore of Nassau County has become too saline for drinking purposes. Ground water contours for 1903, 1933 and 1936 show that these effects are spreading at accelerated rate. Over-pumping and particularly industrial pumping, of magnitude unsuspected prior to 1933, is cause of condition. Coincidentally, safe yield of western end of island has been reduced by building up of territory and construction of streets and sewers, thus diminishing recharge. Annual rainfall averages about 42 inches, equivalent to 2,746 million gallons per day for whole island. More than half of rain is believed to enter ground. Opinions differ as to how much of this water can be recovered

from wells, but it is estimated that if island was developed as unit a yield of 600 million gallons per day might be possible, which is nearly 3 times present total pumpage. Thus, it is not total volume of draft which causes damage, but heavy concentration of draft in western end, where recharge is least and danger of salt water penetration is great. Maximum development requires maintenance of delicate balance between fresh and salt ground water. Engineering problem, which is intricate and unusual, can be solved but legal questions and vested rights seem a more formidable obstacle. At present, only control is that exercised by Water Power and Control Commission acting under two delegations of power: (1) No new public water supply wells can be put down until commission has found that proposed development will be fair and just to other municipalities. (2) No wells of more than 100,000 gallons daily capacity may be put down, except for agricultural purposes, unless commission has found that such wells will not injuriously affect public water supplies. No power has been granted commission to stop pumping from existing wells, nor has commission found itself to be justified in refusing to approve new wells put down as true replacements. Powers of commission have proved to be palliative rather than corrective. Effective control of development of ground water of entire island is essential. This will require enabling legislation, reinterpretation of law as to percolating waters, and development of special engineering technique.—*R. E. Thompson.*

BOILER WATER

Economical Methods of Blowing Down Boilers. G. L. Hubbard. Power Plant Eng., 41: 494 (1937). Heat and water waste by blowing down process may be minimized by following careful schedule and employing heat exchangers.—*T. E. Larson.*

Prevention of Failures of Surface Condenser Tubes. R. E. Dillon, G. C. Eaton, and H. Peters. Power Plant Eng., 41: 496 (1937). Failures were attributed to cavitation followed by corrosion. The formation of vortices with tangential-velocity components resulting in cavitation was eliminated by the use of guide wanes and circulating pumps at reduced speed.—*T. E. Larson.*

Feedwater Filters. H. D. Elfreth. Power, 81: 432 (1937). A brief review of relative advantages of calcite, magnetite, anthracite, quartz, and silica for use as filter medium for boiler feedwaters of various composition and temperature.—*T. E. Larson.*

Feedwater Problems Yield to Research. C. H. Fellows. Power Plant Eng., 41: 34 (1937). Review on present trends in research on feedwater treatment for prevention of corrosion, caustic embrittlement, and foaming.—*T. E. Larson.*

Boiler Water Treated to Prevent Carry Over. J. J. Maguire and J. T. Topolosky. 41: 346 (1937). High organic concentration in feed water and boiler caused foaming, carry over and failure of superheater tubes due to

overheating. Treatment with an organic colloid reduced film stability and resulted in a better quality steam.—*T. E. Larson.*

Carryover from Steam Boilers. H. M. SPRING. Power, 81: 132 (1937). Possible losses due to carryover are listed and a review on cause and correction is given.—*T. E. Larson.*

A-B-C of Water Conditioning. H. E. ROSE. Power, 81: 305 (1937). A brief review is given on present methods for inhibiting scale, corrosion, foaming and priming by feed water treatment.—*T. E. Larson.*

Experiences with Chemically Treated Feed Water for Super-pressure Boilers. WESLY AND GEISLER. Die Chemische Fabrik, 10: 19/20; 197 (1937). Review of feed water treatment in power stations of I. G. Farbenindustrie is given. At Ludwigshafen steam generating plant consisted of one, later three, boilers of four drum bent tube type fired with pulverised coal each for 15400–171600 lbs. per hour evaporation, 7962 sq. ft. heating surface, 1607 lbs. per sq. inch working pressure, 844°F. superheated steam temperature. Only 22,000–30,800 lbs. of condensate being available, make-up is obtained from the river Rhine. Raw water of 100°F. containing 125 p.p.m. carbonate hardness 35 p.p.m. noncarbonate hardness is mixed with milk of lime of approximately 5%, after 6 hours sedimentation and addition of aluminium chloride filtered and completely softened by passage through zeolite filters. After heating to 203°F., phosphoric acid and gaseous sulfur dioxide is introduced, alkalinity being reduced to 12.5 p.p.m., total solids to 110 p.p.m. Alkalinity of boiler water is maintained at 32 p.p.m. sodium hydroxide with phosphate residual of 6.4 p.p.m. P_2O_5. During runs from 5000 to 7800 hours very little scale was formed condition of boiler being always considered satisfactory. There was no sign of corrosion. Composition of non-condensable gases in saturated steam was inconsistent; besides 1–3% carbon dioxide, nitrogen and nitrogen oxide, carbon monoxide hydrogen was developed in amounts from 20 to 40%; as iron content of boiler water decreases and steam of 227 lbs. pressure boilers at Höchst is constantly carrying hydrogen up to 350 ml. per ton steam condensate evolution of hydrogen is considered harmless.

Saturated stem condensate independent from concentration of boiler water continues containing 3 p.p.m. solids, sodium sulfate and chloride, silica being present in amounts never exceeding 0.5 p.p.m. After four months run, blades of high pressure turbine receiving steam at 867 lbs. per sq. in. the exhaust steam passing out at 284 lbs. per sq. in. back pressure showed water soluble deposit mainly of sodium chloride. On turbine blades at temperature range of 482°F., insoluble deposit of 96% silica was observed. Following conclusions were summarized from tests: (1) concentrations of sodium hydroxide in boiler water of 100 p.p.m. result in turbine blade deposits; (2) with concentrations of sodium hydroxide in boiler water from 10 to 25 p.p.m. capacity very slowly diminishes experience of longer runs being needed to draw definite conclusions.

At Höchst three boiler of Löffler-type 88,000–99,000 lbs. evaporation per hour, 1706 lbs. per sq. in. working pressure, 932°F. superheated steam temperature are operated. Water used for steam generation is exclusively ob-

tained from river Main. Cooling water of 122°F. is subjected to a combined thermal-chemical treatment. Carbonate hardness of 89–178 p.p.m. is removed by exhaust steam at 212°F. residual approximately equalling noncarbonate hardness; further softening is completed by sodium hydroxide and in the third stage by disodiumphosphate and heated to 284°F. residual hardness approaching 0.9–1.4 p.p.m. $CaCO_3$. Due to excessive solution of silica from quartz sand filter by hot alkaline water magno-material is used. With feed water of 40 p.p.m. sodium hydroxide and boiler water concentration of approximately 3000 p.p.m., no trouble was experienced in boiler operation saturated steam carrying 3–4 mgm. per kg. solids. Turbine blades showed deposit of 75% sodium hydroxide, being attributed to contamination of superheated steam with boiler water solids. Out of all boiler water constituents sodium hydroxide alone melts at temperature of superheated steam; with decreasing temperature at 608°F. solidification and adhesion takes place. After reducing alkalinity of feed water by neutralization of excess alkalinity with sulfur dioxide no further deposits on blades were observed. Later deposits of nearly pure silica on blades of turbine in the low pressure range appeared which could be washed out with sodium hydroxide solution.—*Manz.*

PUMPS

Water Boosting with Automatic Control at Portsmouth. J. DALRYMPLE. The Surveyor, 91: 777 (1937). The Portsbridge Boosting Station of the Portsmouth Water Company is equipped with centrifugal pumps driven by electric motors and gasoline engines. The main plant includes two centrifugal pumps with a combined capacity of 18 m.g.d. and the stand-by plant includes two 12-inch centrifugal pumps driven by a 72 h.p. Dorman petrol engine. The plant is controlled automatically by pressure gauges regulated by the water pressure. —*H. E. Babbitt.*

Pump Motors with Scheribus Speed Control. ANON. The Engineer (British), 163: 518 (1937). In a single range Scheribus equipment the speed-regulating set takes the place of the rotor resistance of a slip ring induction motor, and returns to the line most of the power which would otherwise be wasted in the resistance. At the same time power factor correction up to unity or a leading value is possible. Efficiency curves, wiring diagrams, and methods of starting and operating the motor are given.—*H. E. Babbitt.*

Raw Water Pumping at Welland, Ontario, Accomplished with a Water Turbine at a Large Saving in Cost. J. C. STREET. Eng. Cont. Rec., 50: 50 (1937). Attention is drawn to the excessive waste of power when pumpage by motor-driven centrifugal pumps is controlled by partial closure of value in discharge line. Obvious remedy is installation of smaller units. At Welland, where excess capacity is available in both low and high lift pumps (latter are driven by water turbines) a 20-horsepower, inward flow reaction turbine and centrifugal pump, using water at pressure of 62 pounds per square inch from high-lift pumps, has been installed to pump raw water. Saving in electric power is expected to pay for installation in 2 years. The electrically driven pumps

have been retained for emergency use. As turbine discharges into pure water well, unit incidentally acts as circulating pump and aids in mixing the chlorine used for sterilization. Since new unit was installed, trouble due to air in filter, believed due to throttling of electric pumps, has disappeared.—*R. E. Thompson.*

Special Features of Three Propeller Pumps in Montreal Low-Lift Pumping Station. ANON. Eng. Cont. Rec., 50: (1937). The low-lift station to deliver water to the recently completed extension to filter plant in Montreal was designed for ultimate capacity of 250 million gallons per day with 5 pumping units, each of 50 million gallons per day capacity. Three of these units have been installed and are in successful operation. Each unit was designed to operate under total dynamic head of 18.5 feet at speed of 400 revolutions per minute and is direct connected by means of Gearflex coupling to shaft of 250-horsepower synchronous motor mounted horizontally on common base-plate. Pumps are of single suction, single stage type, with axial inflow and special casing discharging tangentially, and having 42-inch suction and discharge connections. Pumps occupy considerably less floor space than centrifugal pumps of equal capacity and speed is about 1.5 times higher. Guaranteed overall efficiency of 77% was exceeded in acceptance tests. Contract included five 48-inch gate valves in pump suction mains and five 42-inch gate valves and three 42-inch tilting check valves in discharge mains. Gate valves are of solid wedge disc, inside screw type, with 6-inch by-passes. Check valves were equipped with external dashpot to cushion final disc closure. When operated without dashpot there was perceptible, but by no means severe, thud when disc seated. This is entirely eliminated by dashpot.—*R. E. Thompson.*

Selecting Pumping Equipment. CHARLES B. BURDICK. Eng. News-Rec., 118: 805 (1937). History of art of pumping water in America is reviewed and general principles involved in selection of pumping equipment are discussed. Reliability is first consideration, other features of prime importance being economy of operation and adaptability to particular conditions concerned. Specifications should be limited to results required, thus giving manufacturer widest latitude possible in design so far as consistent with local requirements. —*R. E. Thompson.*

Plant Lubrication. H. A. MURRAY. W. W. Eng., 90: 890 (1937). It is impossible to write one set of specifications that will govern all types of lubricants. The most competent oil technologist would hesitate to select an oil for a steam turbine on the basis of gravity, flash and fire, and viscosity. The viscosity test is the most important of the usual tests made. Author lists in detail what the average oil technologist must know to properly select a certain oil for water works use.—*Lewis V. Carpenter.*

Diesel Reduces Pumping Costs in the Needham Water Works. JOHN W. GREENLEAF, JR., AND BAYARD F. SNOW. Am. City, 52: 47 (1937). A new gravel packed well at Needham, Massachusetts, located in an extensive, deep-lying gravel deposit in the Charles River valley, is designed to provide 1 m.g.d.

when fully developed. Existing water mains were of limited capacity and, although it is intended that these shall be replaced, that could not be done at once. Therefore, any new pumping equipment had to be capable of meeting the present conditions of pumping less than 1 m.g.d. at a higher head and the future ones of 1 m.g.d. against the head which will exist when the new mains are installed. After exhaustive comparison of power and related costs, a single cylinder diesel engine was selected. Details of the pumping station building, the pump and engine mountings, the cooling system and fuel storage facilities are given. Several automatic controls needed because the station will be operated without full time attendance are also described.—*Arthur P. Miller.*

MAINS

Experiences with Chlorinating New Water Mains. GEORGE A. ADAMS AND FRANCIS H. KINGSBURY. J. N. E. W. W. A., 51: 60 (1937). During the summer of 1936 certain Mass. municipalities were given advice on chlorination of new water mains by the Mass. Health Dept. during which difficulties were encountered in obtaining satisfactory bacterial results even after chlorination and thorough flushing. Results in 5 municipalities are tabulated showing persistence of coli-aerogenes bacteria in mains of 158, 75, 46, 12, and 11 days, even with repeated disinfection with chlorine and flushing. Results indicated this effect not due to any polluted matter introduced during the laying of the pipe and led to suspicion of the jute used in joint packing. Bacteriological tests of a number of jute samples were made by placing one gram of sample in 100 cc. sterile water. Bacterial counts were expressed in terms of 1 milligram of sample. Total counts and coli-aerogenes tests were made daily for 12 days or longer on samples standing in water at 70°F. Enormous growth of bacteria resulted showing jute contains food material for the bacteria: Tests for water soluble matter indicated as high as 4.46% present containing 1.58% organic nitrogen. Some of this soluble matter when used instead of peptone and meat extract in nutrient agar provided food for bacterial growth so well that little differences in counts resulted when compared to counts obtained on regular agar. A number of exptl. results are tabulated and prove jute may contain considerable number of coli-aerogenes group bacteria, organic matter suitable for bacterial food, and that disinfection is very difficult to secure. In one lab. test some sterile autoclaved jute was placed in sterile water and inoculated with a pure culture of *E. typhosa* and kept at 70°F. Daily counts on bismuth-sulphite agar showed an increase in number from 7 *E. typhosa* per milligram of jute at the start to a max. in 9 days of 23,000, or 23 million per gram. This number decreased to 700,000 in 14 days. Tests show any jute exposed to water in main may lead to increase in number of bacteria. Of 11 samples of untreated jute all contained coli-aerogenes organisms, and all gave enormous increases in number of these bacteria when in contact with water for 3 days or more. In sterilizing jute with steam, moist steam must penetrate thoroughly into the rope or braids. Thorough boiling should kill coli-aerogenes in jute and cut down food supply. Sanitary significance of such contamination in new mains not known but in author's opinion should not be minimized.—*Martin E. Flentje.*

Chlorination of a Cambridge Main. FRED E. SMITH. J. N. E. W. W. A., 51: 57 (1937). Method is described of chlorinating approx. 10,000 ft. of 30″ C. I. pipe line which had been subjected to pollution hazards during laying. Emergency chlorinator used and dry chlorine gas fed into sections of main shut off from remainder by gate valves. Chlorine dosage used was 12 lbs. per m.g. and main thoroughly flushed after treatment and tested for count and presence of *E. Coli* before placed in service. Total count averaged 1-2 per c.c. and test for colon group was negative.—*Martin E. Flentje.*

Problems in the Design of a Trunk Water Main. E. G. THORP. Civil Eng. (British), 32: 18 (1937). The plan for the Teignmouth Urban District involves the replacement of an existing 9-inch steel main by one of larger capacity but of diameters between 6 and 12 inches. The water is of a soft peaty character and has to be treated to counteract alkalinity. It was decided therefore, to use cement-lined, iron pipe, the whole pipe and lining being dipped in Dr. Angus Smith's solution. The pipes were laid in 18-foot lengths, with a mechanical joint with a lead-tipped rubber ring forced into position by a collar. This allowed a deviation of 5° for a straight line without affecting the efficiency of the joint. Some legal difficulties were encountered in attempting to close highways affected by the construction. Pressure tests on the line, after its completion, were never satisfactory, although a careful examination of the joints and valves revealed no leakage. These difficulties are explained in part by movements of the main under pressure, expansion of pipe and concrete under pressure, absorption of water into the lining, accumulation of air at humps in the line, and absorption of the air by the water. Lack of support offered by the marshy subsoil caused leakages and pipe breakage at one point. This difficulty was overcome by using rigid joints made by forming a concrete collar over them, in the place of the flexible joints which had failed. —*H. E. Babbitt.*

Detection and Prevention of Water Waste. T. A. CECIL. The Surveyor, 91: 649 (1937). The first essential of a water waste detection campaign is suitable operators and the cooperation of the local plumbers and the general public. The next stage is a house-to-house inspection of all water fittings. Stop-tap testing at night should be carried out in conjunction with the house-to-house inspection to locate invisible leaks which may exist in buried pipe. Leakage in the main itself will usually be detected on several stop-taps whose ferrules are in its vicinity. If sound is on one stop-tap only, open the ground down to the ferrule of the service pipe, and if the ferrule is not defective, it should be shut off and the stethoscope placed on it, thus ascertaining on which side of the ferrule the leak lies. Having isolated any wastage to the main itself the engineer is now faced with "working the meters." This may be divided into three steps: (1) Complete plans of the distribution system; (2) Unearthing of buried valves; and, (3) Investigation of cross-overs and other places where different supplies meet. The next stage is a systematic closing down of valves and reading of the results on a suitable waste detecting meter. Having by isolation found in which street leaks exist the next step is to find

the point of leakage. The quickest method is by listening with a stethoscope and then testing with an electric "leak locater."—*H. E. Babbitt.*

Compressed Air Flushing of Small Mains. R. F. BROWN. W. W. and Sew., 84: 141 (1937). Compressed air flushing of small main, mostly 2-inch, proved satisfactory in reducing taste and odor and low pressure complaints.—*H. E. Hudson, Jr.*

Recent Betterments to Buffalo's Distribution System. ALAN D. DRAKE AND WILLIAM J. KELLY. W. W. and Sew., 84: 147 (1937). After careful planning and survey of existing distribution system, Buffalo decided to substitute three strategically placed 2-million gallon elevated storage tanks for old 116-million gallon reservoir. Where city formerly had two pressure districts, only one now exists. More uniform pressures, main velocities, and pumping requirements resulted. Old reservoir site is to be recreational center.—*H. E. Hudson, Jr.*

METERS

Meter Maintenance. CLEM A. GALLAGHER. Eng. News-Rec., 118: 816 (1937). Detailed description and discussion of schedule of routine meter maintenance employed by Louisville Water Company, by which each of the 51,000 meters in use (system is 76% metered) is removed, tested and repaired once every 5 years, although experience has shown that interval between tests could be lengthened appreciably. Routine involves exchange, testing, repair and retesting, and, if accuracy is not within 2% of correct value, meter is returned to bench for further overhauling, this occurring in less than 1% of meters repaired. Cleaning is effected with soap and water, acid being used only when absolutely necessary. Average cost of repairing and testing, exclusive of overhead, is 50¢ per meter. System of records has been developed which assures accuracy, permanancy and simplicity and which dovetails with permanent running inventory of stock of meter parts. Two card records are maintained for each meter, one according to make and serial number and other according to book and page number in meter readers' books. Complete history of every meter is thus available at all times. Experience has conclusively proved that A. W. W. A. specifications for $\frac{5}{8}$-inch cold water meters are entirely too lenient. A well-constructed meter should register much better than 90% on $\frac{1}{4}$-gallon per minute stream. Cost of meter maintenance program is small compared with additional revenue gained, and in addition life of meters is prolonged.—*R. E. Thompson.*